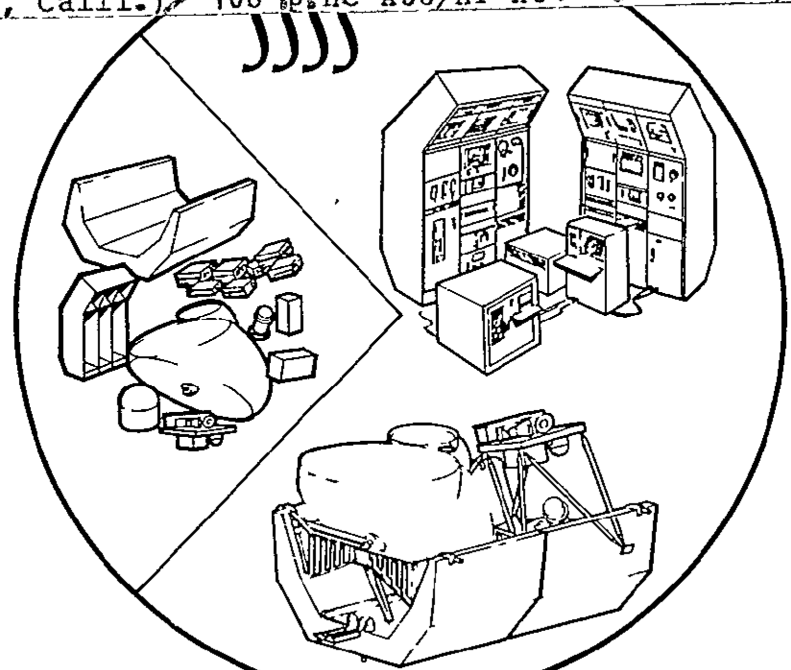
NASA CR 145348
SD 78-SR-0009-4

Spacelab Level IV Programmatic Implementation Assessment Study

FINAL REPORT

AUGUST 1978



Volume IV Executive Summary

PREPARED UNDER CONTRACT NO. NAS1-14909

BY

Space Transportation System Integration & Operations Division
Space Systems Group
Rockwell International

FOR

NASA
National Aeronautics and Space Administration
LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

NASA CR 145348
SD 78-SR-0009-4

FINAL REPORT

AUGUST 1978

SPACELAB LEVEL IV PROGRAMMATIC IMPLEMENTATION ASSESSMENT STUDY

Volume IV
Executive Summary

A. Gianformaggio
Study Manager

PREPARED UNDER CONTRACT NO. NAS1-1
(Paragraph F, Part III)
BY

Space Transportation System
Integration & Operations Division
Space Systems Group

Rockwell International

FOR

NASA
National Aeronautics and Space Administration

LANGLEY RESEARCH CENTER
HAMPTON, VIRGINIA 23665

ACKNOWLEDGEMENT

The Spacelab Level IV Programmatic Implementation Assessment Study was conducted for NASA's Langley Research Center by the Space Division of Rockwell International Corporation under Contract NAS1-14909. Mr. F. O. Allamby was the technical study manager for the Langley Research Center. Mr. Allamby's contributions to the technical content and assistance in the establishment of study concepts and the final analysis of alternatives was extremely beneficial and enhanced the final study products greatly. In addition, Dr. Dale Compton, as chairman of the Technical Advisory Committee, provided valuable assistance to the study with his scientific and technical support.

The study was initially directed by Mr. Larry Hogan and subsequently by Mr. Antonio Gianformaggio. Major contributions were also given by the following Rockwell personnel:

D. B. Anderson	Payload Definition
F. E. Alzofon	Payload Definition
W. G. Antypas	Personnel Estimates
W. J. Carroll	Payload Definition
N. T. Carter	Payload Shared Trade Studies
E. G. Clegg	Payload Design
C. D. Day	Installation and Test Requirements
S. L. Eilenberg	Payload Definition
P. R. Fagan	Payload Definition
J. A. Gerard	Installation and Test Requirements
C. Gerber	Telecommunication
J. A. Heiertz	Alternate Level IV Concepts
E. F. Kraly	Payload Definition
N. R. Keegan	Dedicated Trades and Programmatics
K. R. Murch	Payload Design
N. H. Nelson	Telecommunication
D. E. O'Reilly	Clerical Support
J. W. Patrick	Payload Definition
J. Paul	Installation and Test Requirements
D. H. Robey	Payload Definition
G. R. Surrah	Payload Definition
R. B. Villet	Installation and Test Requirements
J. V. Warren	Payload Design

FOREWORD

The Spacelab Level IV Programmatic Implementation Assessment Study was conducted to assess the Level IV payload integration requirements. In the study, alternate Level IV integration approaches were synthesized and evaluated to establish the most cost-effective experiment integration approach. Resource requirements or cost factors that were included in the assessment pertained to the "hands-on" activities of ground processing. These requirements included manpower, temporary duty subsistence and air fare, flight hardware and Ground Support Equipment (GSE) transportation costs, and prorated flight hardware and GSE use costs based upon the involvement time of these items for each mission. Programmatic inventories of flight hardware and GSE were developed using representative payloads. These payloads were defined to a level of detail that permitted a detailed assessment of the handling, installation, servicing and checkout requirements of the experiment end items. Spacelab flight hardware and GSE support and interface requirements were identified. Buildup schedules for the inventories were formulated. Alternate ground processing concepts were synthesized and the processing of each of the representative payload through these concepts was evaluated. Cost data for each processing option was developed for each payload. The spectrum of experiments and payloads used in the study facilitated the identification of design characteristics to identify the ground processing activities. Guidelines were identified to assist experimenters in the development of payload designs that will permit cost-effective ground processing.

The results of the Spacelab Level IV Programmatic Implementation Assessment Study effort are presented in four volumes:

VOLUME I	REPRESENTATIVE PAYLOAD DEFINITION	SD 78-SR-0009-1
VOLUME II	GROUND PROCESSING REQUIREMENTS	SD 78-SR-0009-2
VOLUME III	OPTIMIZATION AND PROGRAMMATICS	SD 78-SR-0009-3
VOLUME IV	EXECUTIVE SUMMARY	SD 78-SR-0009-4

CONTENTS

CONTENTS (CONT'D)

ILLUSTRATIONS

TABLES

1.0 INTRODUCTION

1.0 INTRODUCTION

The progression of definition, design, and development of the Space Shuttle has reached the point where the ground processing approach has evolved from an objective, to an allocation and, hence, to an assessment stage. A similar, but slightly delayed, evolution has occurred with Spacelab ground processing approaches. This continuing refinement and redefinition has paralleled and reflected the maturing nature of the equipment design and development. The current status of the definition of some of the Spacelab payloads and individual experiments is at the point that a quantitative assessment of the ground processing requirements of these elements is feasible and practical at this time.

In previous studies pertaining to the ground processing of Spacelab payloads, the scope of these studies was limited to Levels III, II, and I integration activities. Preliminary estimates of the recurred quantities of Spacelab flight hardware have been derived from an analysis of only these phases of the Spacelab ground processing scenarious. However, Spacelab unique flight hardware requirements will also be directly affected by Level IV integration activities.

The definition and scope of the four level of Spacelab integration are

- Level IV Integration - Integration and checkout of experiment equipment with individual experiment mounting elements (e.g. racks and pallet segments).
- Level III Integration - Combination, integration and checkout of all experiment mounting elements (e.g. racks, rack sets and pallet segments) with experiment equipment already installed.
- Level II Integration - Integration and checkout of the combined experiment equipment and experiment mounting elements (e.g. racks, rack sets and pallet segments) with the flight subsystem support elements (i.e. core segment, igloo) and experiment segments when applicable.
- Level I - Integration and checkout of the Spacelab and its payloads with the Shuttle Orbiter, including the necessary pre-installation testing with simulated interfaces

In this study, a representative set of four Spacelab payloads (Advanced Technology Laboratory-ATL, Space Processing-SP, Life Science-LS, and Combined Astronomy-C/A) and experiments were defined to a level of detail that permitted a quantitative assessment of their Level IV integration requirements. Trades and analyses were conducted on alternate Level IV integration concepts for the four representative payloads to determine the most cost-effective approach that would be responsive to experimenter requirements, and compatible with subsequent higher-level integration activities.

Programmatic requirements were derived from an extrapolation of the data developed for the four representative payloads to the baseline Spacelab Traffic Model ("560 Traffic Model) and to two other traffic models (a 2/3 and 1/3 baseline) that were developed from the baseline model. The programmatic resource requirements or cost factors that were defined pertained to the "hands-on" portion of Level IV integration. "Hands-on" relates to those activities directly involved in the physical integration of experiment equipment to the Spacelab mounting elements. It includes not only the installation of the experiment equipment but also the use of Spacelab and PI provided GSE to perform the functional verification (nominal operations) of the experiments. The requirements were developed for manpower, temporary duty (TDY) assistance, Spacelab flight hardware, GSE, and transportation costs.

This volume of the study documentation contains a succinct summary of the study activities that were conducted to establish the Spacelab Level IV integration requirements for the representative payloads including the trades and analysis conducted to assist in the definition of a preferred, most cost-effective, processing approach.

The Executive Summary defines the overall study objectives (Section 2.0), as well as a summary of the most significant results (Section 3.0) of the analysis of the study. Section 3.0 defines the approach used in the synthesis and selection of alternate Level IV integration approaches, namely the Distributed Site Options, the Lead Center Option, and the Launch Site Options. The principal characteristics as well as the functional flow diagrams for each options are presented and explained.

In order to provide a broad spectrum of Level IV integration ground processing requirements, four types of Spacelab payloads were analyzed in this study. These payloads are considered to be representative of the Spacelab traffic model. The design reference missions analyzed were:

1. Space Processing. — A single pallet payload that is representative of materials development and industrial applications activities, which would be part of a mixed cargo Orbiter flight.

2. Combined Astronomy. — A five pallet payload that is representative of astrophysics, solar terrestrial, and astronomy investigations.

3. Life Sciences. — A long module payload that is representative of aerospace bioscience and physiological investigations.

4. Advanced Technology Laboratory — A short module plus pallet train payload that is representative of multi-disciplines technological investigations.

Experiments and configurations for these types of payloads were defined to various levels of detail in previous NASA and contractor studies. In this study, these data were expanded and integrated into representative payloads to a depth that would permit assessment of ground processing activities. A synopsis of the experiments and flight configuration for each of the four representative payloads is presented in subsequent sections of this volume.

Ground processing requirements and optimizations were established for each payload. The guidelines utilized to define the ground operations applicable to each payload are provided. The ground processing standardized task estimating techniques are defined and their application explained. Level IV integration resource requirements are included for each payload and applicable ground processing option. Cost summaries of these permission ground processing costs are presented in these analyses.

A summary of the three special system level trade studies is included. One study evaluated the use of simulated or substitute Spacelab unique equipment such as Remote Acquisition Units (RAU's), Spacelab module floors, flight cables, etc. The other two studies were an analysis of dedicating Spacelab flight hardware to experiments and the potential cost implications of shared (progressive) Spacelab integration.

Section 3.4 of the Executive Summary defines the programmatic costing of the resource requirements for the four representative payloads. The resource requirements of Personnel, Spacelab Flight Hardware, GSE and Transportation are defined for each of the Level IV ground processing options and traffic models selected to be evaluated as part of the programmatic analysis. Summaries of these data are presented in this volume.

The final sections (3.5, 3.6 and 3.7) contain the concept evaluations including the qualitative assessment of options, the design and integration guide - developed as a result of the experience gained in the conceptual integration of payloads during the course of the study, and the summary of the study - with its major study conclusions and recommendations.

2.0 STUDY OBJECTIVES

2.0 STUDY OBJECTIVES

2.0 STUDY OBJECTIVES

The overall objective of the Spacelab Level IV Programmatic Implementation Assessment Study was to develop alternate Level IV integration approaches to be synthesized and evaluated to establish how the most cost-effective Level IV integration approach should be performed. This analysis was accomplished in sufficient detail, and supported by sound ground rules, guidelines, facts, and analyses, to assist the NASA in its definition of and planning for the Spacelab operations.

Resource requirements or cost factors that were included in the assessment pertain to the "hands-on" activities of ground processing. These requirements include manpower, temporary duty subsistence and air fare, flight hardware and GSE transportation costs, and flight hardware and GSE use costs based upon the involvement time of these items for each mission. Programmatic inventories of flight hardware and GSE were developed. Buildup schedules for the inventories were also formulated and analyzed. The spectrum of experiments and payloads used in the study were selected to facilitate the identification of design characteristics that are representative of the ground processing activities.

The four primary objectives that were established to achieve the overall study objectives were (1) synthesis and assessment of alternate Level IV integration approaches, (2) derivation and identification of Level IV integration and checkout requirements and the optimization of each of the processing concepts/options, (3) development of NASA Level IV programmatics for the Spacelab operational era, (4) evaluation of selected concepts to identify the most cost-effective expeiment/payload integration approach(es). The key factors and considerations associated with each primary objective are delineated below.

SELECTION OF ALTERNATE LEVEL IV INTEGRATION APPROACHES

An approach was formulated in which three major Level IV integration ground processing concepts were considered: distributed site, centralized site, and launch sites.

The scenario for the distributed sites concept began with the preparation and shipment of Spacelab flight and GSE equipment from KSC to the Principal Investigator (PI). There was also an option to this concept that considered the provisions and resource requirements for the processing of the experiment/Spacelab equipment in a combined payload checkout at the launch site (in a payload assembly and checkout area) prior to the initiation of the Level III/II integration activities at KSC. The centralized site scenario commenced with the preparation and shipment of both experiment and Spacelab flight and GSE equipment to the centralized site, and terminated with the shipment of experiment equipment from the launch site back to the PI's. The launch site scenario begins with the shipment of experiment flight equipment directly from the PI to the launch site, and ends following deintegration when the experiment equipment is shipped back to the PI's.

REQUIREMENTS AND OPTIMIZATIONS

As an integral part of the derivation of Level IV integration requirements, the development of installation and physical support requirements were established for four design reference missions. These payloads were selected because they are considered representative of the Spacelab traffic model. The payloads analyzed were:

1. Space Processing	A single pallet payload that is representative of materials development and industrial applications activities, which would be part of a mixed cargo Orbiter flight.
2. Combined Astronomy	A five pallet payload that is representative of astrophysics, solar terrestrial, and astronomy investigations.
3. Life Sciences	A long module payload that is representative of aerospace bioscience and physiological investigations.
4. Advanced Technology Laboratory	A short module plus pallet train payload that is representative of multi-disciplined technological investigations.

The ground processing requirements were established by the (1) definition of the installation and test (I&T) requirements, and (2) the development of ground processing sequences for each experiment. The resources required to process each of the representative payloads in accordance with the alternate Level IV concepts developed were determined for:

- "Hands-On" manpower levels required for each Level IV related activity
- TDY costs
- Spacelab flight hardware quantities
- Level IV integration GSE
- Transportation costs for Spacelab and experiment equipment being shipped to/from an integration site to the launch site.

Three major trades were conducted to establish the most cost-effective approach for each of the three ground processing concepts (Distributed, Centralized, Launch Site) evaluated. The use of simulated and dedicated Spacelab unique equipment were evaluated. In addition, the cost and schedule implications of progressive Level IV integration of shared Spacelab flight hardware were defined and assessed.

PROGRAMMATIC COSTING

An extrapolation of the baseline ground processing requirements, generated for the four representative payloads, was made to the entire Spacelab traffic model. This extrapolation was made by establishing an equivalency between the four representative payloads and the remainder of the traffic model. The experiment definitions and conceptual designs developed for each representative payload were used as guides in the establishment of the distinguishing payload characteristics.

The resource requirements for the preferred approach for the four representative payloads were scheduled for the appropriate equivalent payload of the traffic model. Programmatic schedules and cost summaries have been prepared to provide composite costs. Required inventories of Spacelab unique flight and ground equipment simulators and major common support items were defined.

A selection was made and not all ground processing options defined in the requirements analysis were carried into the programmatics evaluation. The definition of the six viable ground processing options selected to be carried through the programmatics are defined in Section 3.3 of this document.

The results of the system level trades are factored into the programmatics data presented in this document.

CONCEPT EVALUATIONS

In addition to the Baseline traffic model, 2/3 and 1/3 traffic models were established. Based upon the payload equivalencies established resource requirements for the 1/3 and 2/3 Spacelab traffic models were derived. These reduced traffic models were used in the evaluation of the differences between options and within concepts.

In addition to the analysis and evaluation of the specific ground processing resource requirements developed for each of the applicable options and for each representative payload, there was a qualitative assessment performed. This qualitative assessment is a relative comparison of the Personnel, Facilities, GSE, Operations, and Management aspects of the Level IV options evaluated. This assessment is presented in Section 3.5.

3.0 SIGNIFICANT STUDY RESULTS

3.0 SIGNIFICANT STUDY RESULTS

This section presents a summary of the more significant results of the analysis of the study. The subsections in this section correspond to the four primary objectives of the study described in Section 2.0, Study Objectives.

3.1 SYNTHESIS AND SELECTION OF ALTERNATE LEVEL IV INTEGRATION APPROACHES

In the establishment of the alternate Level IV integration approaches, three Level IV integration ground processing concepts were considered: (a) distributed site, (b) centralized site, (c) launch sites. The distributed site concept reflected multiple Level IV integration activities for a single Spacelab payload at geographically separated locations. The centralized site concept required all experiment equipment and Spacelab mounting/interfacing hardware for a payload at one geographical location. The third concept required all experiment hardware at the launch site, KSC. All three concepts reflect the same level of assembly and checkout prior to initiation of Level III/II integration activities at KSC. To provide a broader spectrum of data, the number of options within each concept was expanded. The expansion within the three baseline or generic concepts was based upon variations in the experiment/payload integration.

DISTRIBUTED SITE OPTIONS

The principal characteristic of distributed site options is the independent buildup and checkout of Spacelab mounting elements at multiple geographical locations. For example, an experiment system could be installed and checked out in one rack at a site, while other experiment systems were being installed and checked out independently in other racks at other sites. Multiple sets of checkout equipment are also characteristic of this generic concept.

The analysis of the four representative payloads resulted in the definition of 15 candidate distributed sites. By payload, there were 8 for Life Science, 3 for Combined Astronomy, 3 for Advanced Technology Lab, and 1 for the single pallet Space Processing payload.

There were three distributed site options that were defined for analysis (A-1, A-2, and A-3). The A-1 option reflects rack/floor and/or pallet train assembly during the STS operations. Also in the A-1 option, the initial checkout of the integrated payload is accomplished after rack/floor installation into the module interconnection of the habitable module and pallet(s), and/or installation of the Igloo on the lead pallet and interconnection of pallets.

A functional flow diagram for this option is presented in Figure 3-1. A brief description of the activities conducted in each block is presented in Volume II, Section 2.0 (Table 3-1). The missing numbers will be subsequently assigned and the activities identified in subsequent option definitions.

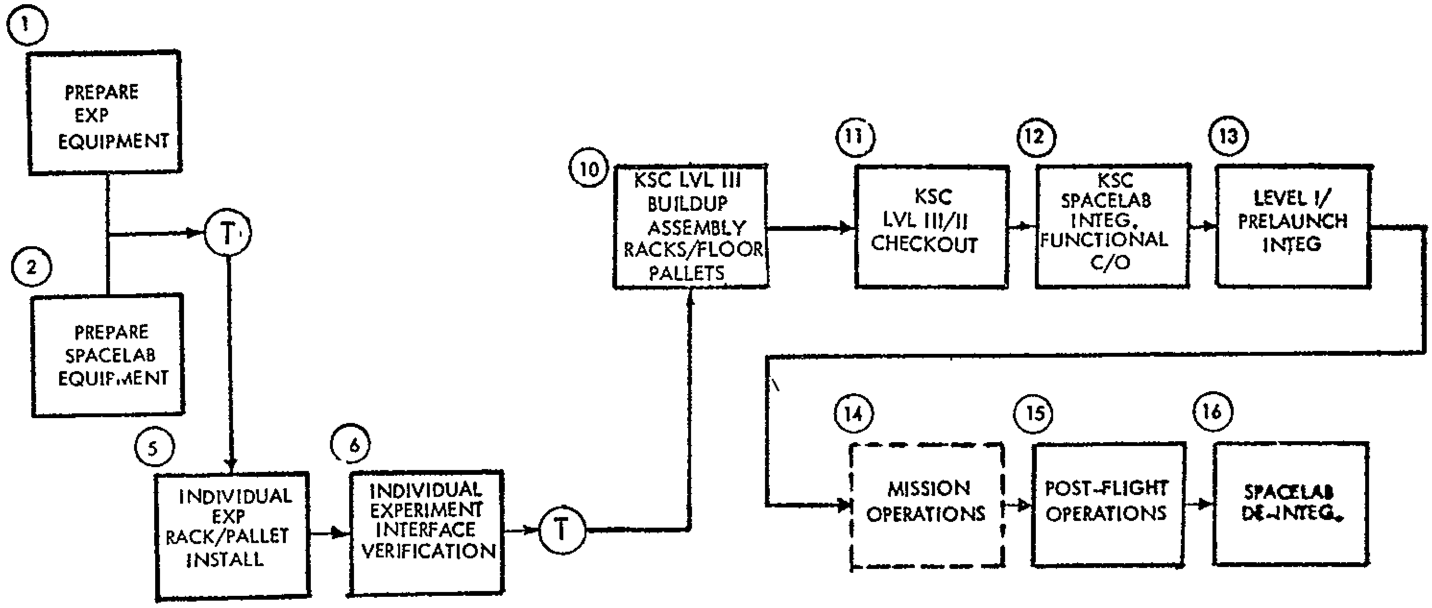


Figure 3-1. Individual Experiment Integration - Level III/II Assembly and Checkout

The second distributed site option (A-2) reflects combined payload checkout at KSC after independent/individual experiment/mounting element integration at multiple distributed sites but prior to entering STS operations in the O&C building. This option is also characterized by the by-passing of the Level III assembly activity in the O&C building. For example, independently integrated pallets or pallet trains (pallet-only payload) would be interconnected and checked out at the payload level in the off-line activity, disconnected, and then transported directly to the Level II stand in the O&C building.

The third distributed site option (A-3) also includes off-line checkout at the payload level at KSC. However, in this option, Level III assembly in the O&C building is required. For example, rack/rack sets from multiple distributed sites would be interconnected and checked out in the off-line activity, disconnected and transported to the O&C building, and then integrated with floor segments in the Level III assembly stand.

A functional flow diagram for the A-2 and A-3 options is presented in Figure 3-2. The delta activities for these options are reflected in functional blocks 7, 8 and 9. All other functional blocks are essentially the same as described in Volume II, Section 2.0 (Table 2-1). Activities in blocks 7, 8 and 9 are summarized in Volume II, Section 2.0 (Table 2-2). The destination from block 9 is dependent upon the configuration of the payload upon arrival at the O&C building. If the payload is in the flight configuration, the flow by-passes block 10 (Option A-2). If Level III assembly is required, block 10 is included in the processing flow (Option A-3).

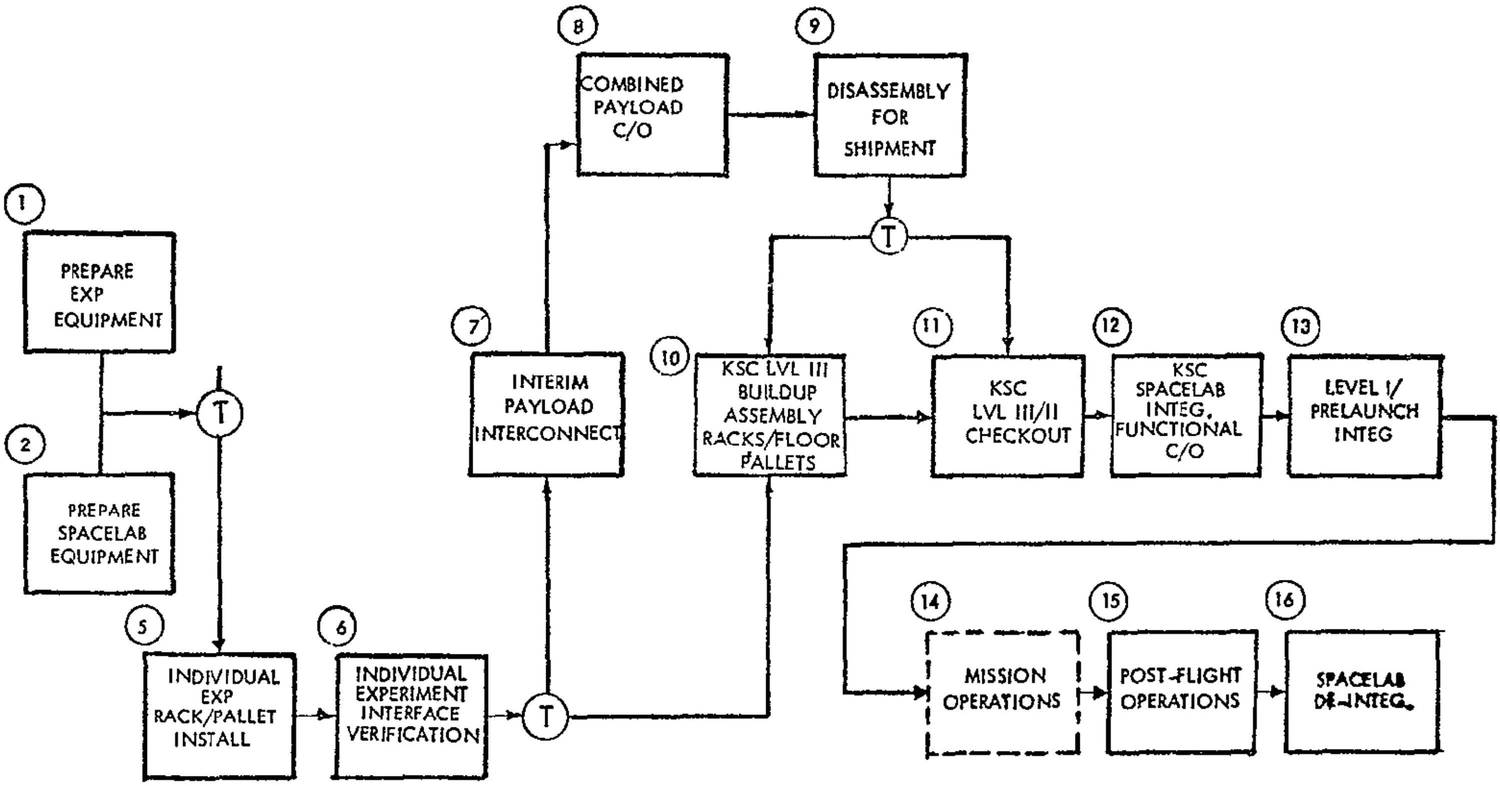


Figure 3-2. Individual Experiment Integration - Pre-Level III/II Combined Checkout

LEAD CENTER OPTIONS

The generic lead center concept is characterized by the performance of all pre-O&C building integration activities at one geographical location other than KSC. The options within this concept reflect variations in both the level of and approach to assembly and checkout. There was one Lead Center selected for each of the representative payload groupings - Life Science, Combined Astronomy, Space Processing, and Advanced Technology Lab.

The first three lead center options (B-1, B-2 and B-3) are similar to the distributed site options. Although experiment system/mounting element integrations are conducted on an individual basis, the activities are scheduled to maximize the common usage/sharing of GSE. The first option (B-1) would result in the integration of individual mounting elements at a lead center. Subsequently, these elements would be transferred to KSC for assembly into the flight configuration of the payload in the O&C building. Option B-1 is comparable to Option A-1.

Options B-2 and B-3 are comparable to Options A-2 and A-3 with regards to pre-KSC/STS assembly and checkout status. However, the combined payload checkout activity would be conducted at the lead center rather than in an off-line facility at KSC.

Except for the location(s) of this activity, the functional blocks in Figure 3-1 and -2 for Options A-1, A-2 and A-3 are the same for B-1, B-2, and B-3, respectively.

If Level IV integration is conducted at one geographical location installation of the full complement of experiment equipment and/or Spacelab mounting elements prior to checkout is feasible. Option B-4 reflects this possibility. For example, an entire rack/floor set would be available at the Level IV site. Intra- and inter-rack and floor cabling would be installed. Experiment equipment would be installed in/on the racks and floor segments. Individual experiment systems would be checked out followed by a combined payload checkout. The totally assembled and integrated payload would then be transported directly to the Level II stand in the O&C building.

In order to assess the impact on ground processing of a potential road transportation constraint, a fifth lead center option (B-5) was introduced. Repetitive road transportation through some states may be restricted to a maximum width of twelve feet. This constraint can be met if only single pallet and/or single module rack/floor sets are transported. Thus, for the B-5 option, payload assembly and preparation for shipment activities in the B-4 option were revised to reflect the temporary interconnection if pallet trains and long module rack and floor sets. Also, the Level III assembly activity in the O&C building was included in the KSC-STS operations.

The top level functional flow for the B-4 and B-5 options is presented in Figure 3-3. Only functional blocks 3 (Experiment Installation and Payload Assembly) and 4 (Experiment Interface Verifications) are deltas to the flow presented in Figure 3-1. Block 3 encompasses the installation of experiment equipment in flight configured rack/floor sets and/or pallet trains. Block 4 includes the sequential and progressive verification of individual experiment systems. The activities within blocks 8, 9 and 10 are similar to those of the previously discussed options, but reflect the integrated payload configuration of Options B-4 and B-5.

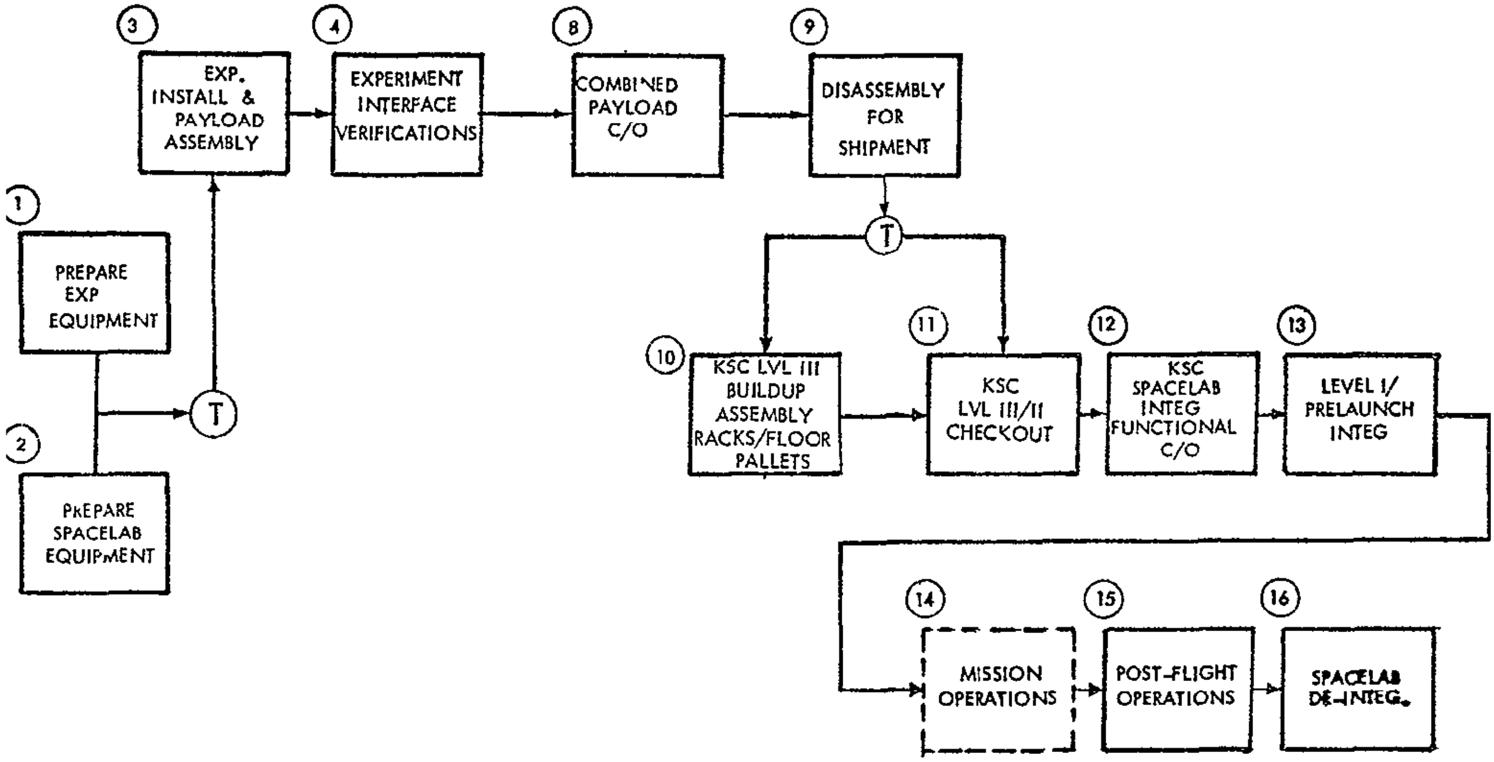


Figure 3-3. Payload Assembly and Checkout - Disassembly for Transportation

LAUNCH SITE OPTIONS

In general, the launch site options are a special application of the centralized options. All experiment equipment and Spacelab mounting elements are integrated at one geographical location. For purposes of this study, it was assumed that all the Level IV integration activities at the launch site would be conducted in a facility in the industrial complex. The one disparity between the centralized options and the launch site options is that there is no launch site option comparable to B-5. A twelve-foot width constraint during transportation of an integrated payload from the industrial complex to the O&C building at the launch site is not applicable.

SUMMARY OF GROUND PROCESSING OPTIONS

A matrix of the twelve options for the three generic concepts and the applicable functional flocks is presented in Figure 3-4. As stated previously, the first three options for each generic concept encompass the same functional blocks (activities). Options B-4 and C-4 are comparable, Option B-5 is unique to the lead center concept.

OPTION	DESCRIPTOR	APPLICABLE ACTIVITY BLOCK															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A-1	IND EXP C/O	PI	LS			D	D				LS	LS	LS	LS	LS	LS	LS
A-2	IND EXP C/O-INT EXP C/O-ONLA	PI	LS			D	D	LS	LS	LS		LS	LS	LS	LS	LS	LS
A-3	IND EXP C/O-INT EXP C/O-OFLA	PI	LS			D	D	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS
B-1	DEP EXP C/O	PI	LS			C	C				LS	LS	LS	LS	LS	LS	LS
B-2	DEP EXP C/O-INT EXP C/O-ONLA	PI	LS			C	C	C	C	C		LS	LS	LS	LS	LS	LS
B-3	DEP EXP C/O-INT EXP C/O-OFLA	PI	LS			C	C	C	C	C	LS	LS	LS	LS	LS	LS	LS
B-4	P/L ASSEMBLY-C/O- ONLA	PI	LS	C	C				C	C		LS	LS	LS	LS	LS	LS
B-5	P/L ASSEMBLY-C/O- OFLA	PI	LS	C	C				C	C	LS	LS	LS	LS	LS	LS	LS
C-1	DEP EXP C/O	PI	LS			LS	LS				LS	LS	LS	LS	LS	LS	LS
C-2	DEP EXP C/O-INT EXP C/O-ONLA	PI	LS			LS	LS	LS	LS	LS		LS	LS	LS	LS	LS	LS
C-3	DEP EXP C/O-INT EXP C/O-OFLA	PI	LS			LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS
C-4	P/L ASSEMBLY-C/O-ONLA	PI	LS	LS	LS				LS	LS		LS	LS	LS	LS	LS	LS

LEGEND

A-X DISTRIBUTED SITE OPTIONS
B-X CENTRALIZED SITE OPTIONS
C-X LAUNCH SITE OPTIONS

IND	INDEPENDENT
EXP	EXPERIMENT
C/0	CHECKOUT
OFLA	OFF-LINE ASSEMBLY
D	DISTRIBUTED SITE
LS	LAUNCH SITE
ONLA	ON-LINE ASSEMBLY
DEP	DEPENDENT
INT	INTEGRATED
P/L	PAYLOAD
PI	PRINCIPAL INVESTIGATOR
C	CENTRALIZED SITE

Figure 3-4. Matrix of Processing Options

The predominant discriminators between options are as follows:

1. Level of pre-KSC/STS integration· Inclusion/exclusion of Combined Payload Checkout - Block 8.

2. Approach to experiment installation. Individual experiment versus payload buildup - Blocks 5 and 6 versus Blocks 3 and 4.

3. Level III assembly at KSC: Inclusion/exclusion of payload flight configuration buildup at KSC - Block 10.

Various combinations of A, B, and C options for the ground processing of a payload were briefly examined. Some combinations or hybrids are feasible and quite reasonable. For example, part of a payload might be integrated at a distributed site (A type option) and then combined with the remainder of a payload at a lead center (B type option) prior to transfer to KSC. The assessment of these types of hybrid options would not significantly expand the spectrum of data of the basic twelve options. Also, the data for the twelve options could be extrapolated to various hybrids if other factors indicated the desireability of a hybrid ground processing approach for an individual payload.

3.2 DESIGN REFERENCE MISSIONS

In order to provide the depth of detail necessary to establish the wide spectrum of Level IV integration ground processing requirements, four types of payloads were analyzed in this study. The payloads analyzed were:

1. Space Processing
2. Combined Astronomy
3. Life Sciences
4. Advanced Technology Laboratory

The experiments that these payloads accommodated and the different types of payloads were defined to various levels of detail in previous NASA and contractor studies. In this study, these data were expanded and integrated into representative payloads to a depth that would permit assessment of ground processing activities. A summary of the experiment definition process the experiment complement on each payload and their conceptual designs is presented in the following subsections.

EXPERIMENT DEFINITIONS AND REQUIREMENTS

Four payloads (Combined Astronomy, Life Science, Space Processing, and the Advanced Technology Laboratory) were selected for use in the study because they were representative of the majority of the payloads of the Spacelab traffic model. The Orbiter cargo manifest for the Space Processing payload will include two free-flyer payloads to assess potential implications of a mixed cargo on Level IV integration. This payload and Combined Astronomy are pallet-only payloads. The Life Science payload is representative of the module-only cases and utilizes the long module Spacelab configuration. Advanced Technology Lab (ATL) configuration is a short module plus two pallets.

Each of the experiments of these payloads is described by means of an experiment definition package (EDP), illustrated in Figure 3-5, consisting of 13 different kinds of pages. The EDP covers experiment objectives, ground operations, component physical properties and power, thermal control, and environmental requirements, and data interphases. The level of detail is that necessary to establish a payload conceptual design and to define the individual experiment Level IV integration requirements. The form was utilized to assure a standard depth and format of definition for all experiments.

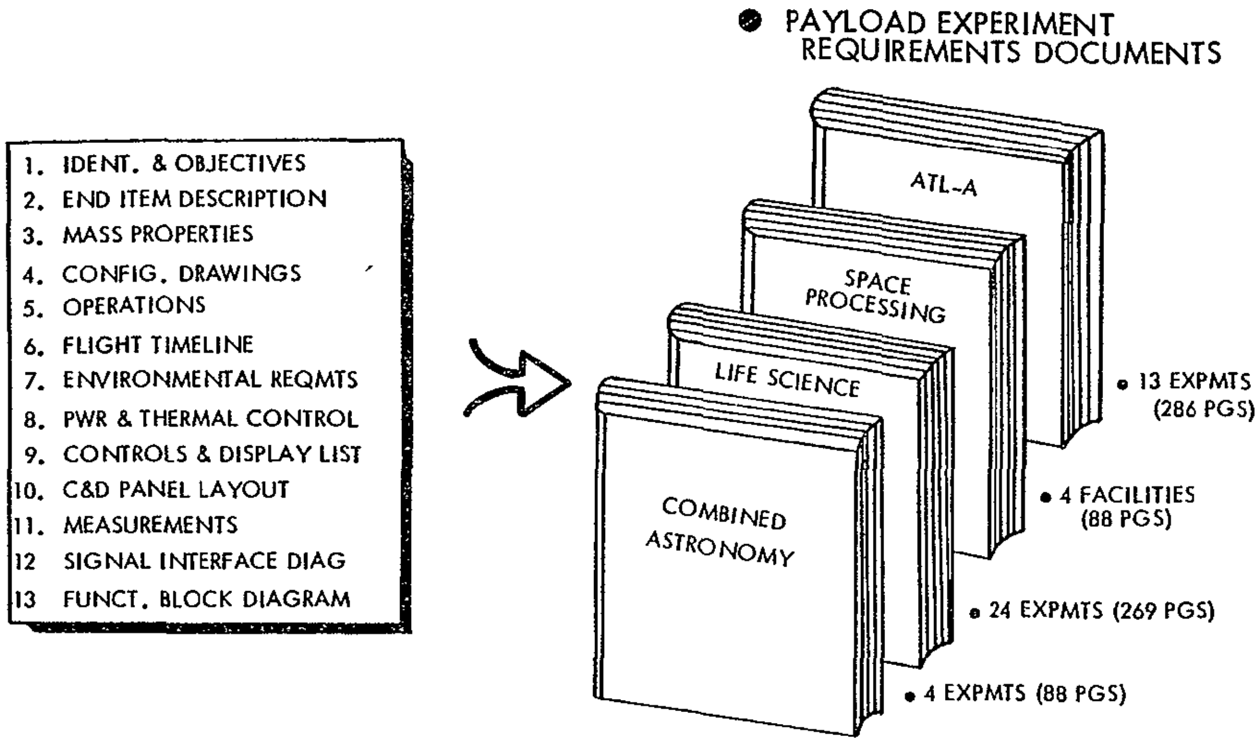


Figure 3-5. Development of Experiment Definitions and Requirements

SPACE PROCESSING PAYLOAD

The representative single pallet/mixed cargo Spacelab payload used in this study was an adaptation of the Space Processing payload defined in previous NASA studies, including contract NAS8-31495. The other cargo elements considered were SSUS-D's with a telsat and a Small Business Satellite payload. A Spacelab mixed cargo was included to assess potential implications of such a configuration on Level IV ground processing activities.

Scheduling, mission planning, resource management, thermal and structural analysis, crew training, and KSC-STS operations will be affected by a mixed cargo configuration. These impacts will be reflected in the analytical engineering and integration activities of Level IV integration. However, Level IV ground processing, which is the only Level IV integration activity addressed in this study, will not be affected by a mixed cargo configuration.

Significant ground processing interfaces between a Spacelab payload and free flyers were identified during only two STS operations activities, installation and checkout of Orbiter aft-flight-deck control and displays (for the cargo), and final servicing and interface verification of cargo elements at the pad. Neither of these activities impose constraints/requirements on the Level IV ground processing activities of a Spacelab payload.

Experiment Complement

The experiments included in the Space Processing payload are listed in Table 3-1.

Table 3-1. Experiment Complement for Space Processing Payload

EXPMT NO.	TITLE
CG-5	Containerless/Melting of Blanks for Earth Drawing Optical Fibers
CG-7	Space Processing of Chalcogenide Glasses
S-4	Preparation of High Point Defect Density Expitaxial Films
S-6	Floating Zone Melting of Silicon
S-7	Liquid Phase Epitaxial Film Growth
S-9A	Evaporative Purification of Metals
S-9B	Controlled Solidification Morphologies
S-14	Crystal Growth by Chemical Vapor Transport
S-16	Crystal Growth from Quiescent Melts
S-21	Evaporative Purification
S-25	Containerless Zone-Growth ALSb Crystals

A complete definition of the experiments and the space processing facilities that they utilize is contained in Section 2.0 of Volume I Representative Payload Definition.

Payload Configuration

The configuration and end item callouts are illustrated in Figure 3-6. The only Spacelab interfacing equipment illustrated is the RAU and EPDB. However, coldplates, interconnect stations (I/C) and connector brackets are also included in the configuration. It was assumed that installation of all Spacelab interfacing equipment (including interconnections between coldplates) is performed during staging activities at KSC. All other

end items are installed as part of the Level IV activity. It should be noted that the freon pump and heat exchangers indicated in the figure are experiment unique equipment (for the furnace quench systems) and are in addition to the heat exchangers/coldplates and freon pump provided as part of Spacelab interfacing equipment.

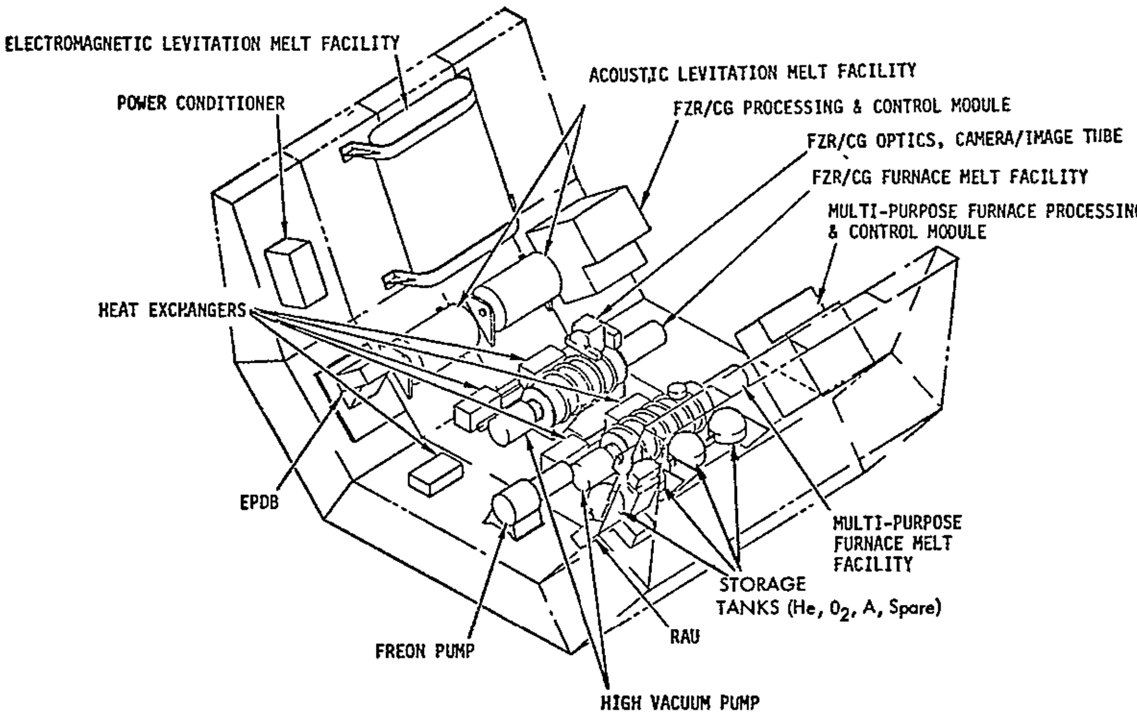


Figure 3-6. General Arrangement-Space Processing

ORIGINAL PAGE IS
OF POOR QUALITY

COMBINED ASTRONOMY PAYLOAD

The Combined Astronomy payload is representative of the planned astrophysics investigations and encompasses typical payload elements and configuration requirements.

Experiment Complement

The experiments included in the Combined Astronomy payload are listed in Table 3-2.

Table 3-2. Combined Astronomy Experiment Complement

EXPMT NO.	TITLE	CENTER
AS-01-S	Shuttle Infrared Telescope Facility (SIRTF)	ARC
UV-2	UV Photometer/Telescope	GSFC
GR-1	Medium Gamma Ray Telescope	GSFC
AS-05-S	Far UV Schmidt Camera/Spectrograph	GSFC

The four sets of experiment equipment making up the combined astronomy representative payload, reflect developments of two NASA centers. Ames Research Center has project direction for the 1.6-meter, cryogenically-cooled telescope. The overall mission objectives are to observe cool objects ($\leq$ 4000 K) and identify sources of infrared radiation in the 1-1000μm wavelength region.

The Goddard Spaceflight Center complements include some of the many instrument complements undergoing stúdy. The UV photometer/telescope assembly is designed to feed detectors with sensitivities ranging from 900 Å to 3400 Å. The medium energy gamma ray telescope will be designed to perform detailed exploration of the $8 < E < 150$ Mev radiation emissions. The far UV Schmidt camera/spectrograph will have the objective of obtaining spectra in the range of 950 Å to 2000 Å with particular emphasis on UV flux distributions.

The above experiments provide for a complementary group with compatible flight mode and pointing requirements, and a range of unique Level IV integration activities.

Payload Configuration

The Combined Astronomy representative payload is shown in Figure 3-7 in its integrated pre-Level III configuration. The first pallet installation (left on the viewgraph) contains one of the GSFC experiment groups. The pallet installation is characterized primarily by its integration with the Small Instrument Pointing System.

The next three pallets make up the ARC Shuttle Infrared Telescope Facility (SIRTF). The assembly starts with a single pallet containing the Instrument Pointing System, which is physically engaged to the SIRTF telescope after orbit insertion. The next two pallets are entrained and support the 1.6 meter telescope and is instruments, cryo cooling and ancillary systems. The fifth pallet contains the GSFC fixed installation, Gamma Ray Detector.

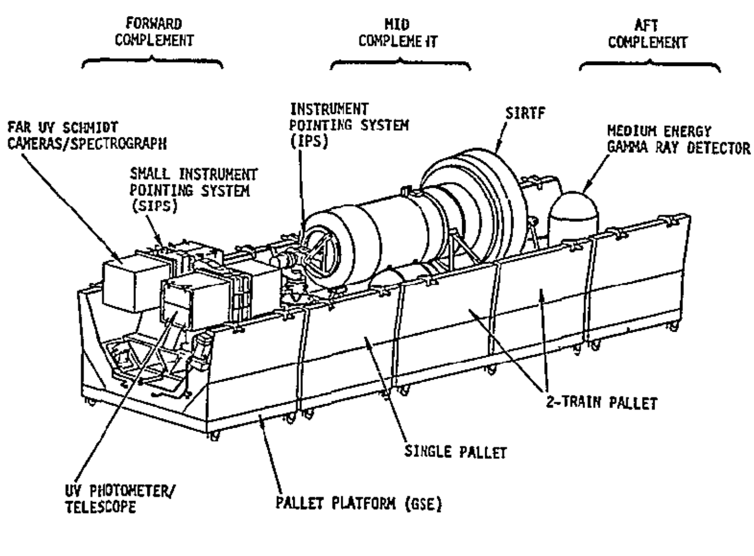


Figure 3-7. General Arrangement-Combined Astronomy

This particular five pallet segment configuration is not included in Orbiter-Spacelab interface control documents. However, mass and center-of-mass characteristics of this configuration were assessed and were within both Orbiter and Spacelab design constraints. The total payload weight at liftoff is 32,880 pounds (14,945 Kg) and at landing 31,925 pounds (14,511 Kg).

LIFE SCIENCES PAYLOAD

The Life Sciences payload used in this study consists of a representative experiment complement that uses the Spacelab long module configuration. Twenty-three experiments are contained in the module; one experiment is installed in the payload station of the Orbiter AFD.

The complement of experiments and experiment equipment used as the representative Life Sciences payload are an adaptation of the joint JSC/ARC simulation, LB-SMD-III-1 dated December 31, 1976. Modifications were incorporated to reflect Spacelab and operational constraints.

Experiment Complement

The experiments included in the Life Sciences payload are listed in Table 3-3. The details of each of these experiments is contained in Section 3.0 of Volume I (Payload Requirements Definition).

Table 3-3. Life Science Experiment Complement

	Expt No	Title	Study Contract Center
(1)	X-3	Rat Collagen Turnover	ARC
(2)	X-5	Biofeedback	ARC
(3)	X-8	Insulin Resistance	ARC
(4)	X-10	Rat Plasma Somatomedin Concentration	Stanford/ARC
(5)	X-11	Rat Urinary Excretion of 3-Methyl Histidine	ARC/JSC
(6)	X-12	Rat Proteolytic Concentration in Muscle	Univ of Texas/ARC
(7)	X-13	In Vivo Muscle Protein Degeneration	Univ. of California/ARC
(8)	X-15	Monkey Static-Otolith Activity Change	ARC
(9)	X-21	Mice Vestibulo-Cerebellum-Vomiting Center and Hypothalmic-Pituitary-Endocrine Axis	ARC
(10)	X-23	Rat Brain & Renal Renin-Angiotensin Alteration	Penn State/ARC
(11)	X-27	Rat Lymphoid Tissue Histopathological Changes	ARC
(12)	X-39	Monkey Resorption Rate Changes	ARC
(13)	X-42	Drosophila Development and Aging	ARC
(14)	X-49	Human Cardiovascular Alteration	Stanford/ARC
(15)	X-51	Motion Sickness Factors	San Jose State/ARC
(16)	X-58	Human Pulmonary Function	UCSD Sch of Med

Table 3-3. Life Science Experiment Complement (Cont'd)

	Expt No.	Title	Study Contract Center
(17)	X-59	Rat Metabolism and Heat Balance	ARC
(18)	X-60	Rats Pyrogenic Fever-Salicylate Interaction	ARC
(19)	X-66	Otolith Response Adaptation as a Function of CNS Output	JSC
(20)	X-68	Erythrokinetics in Man	JSC
(21)	X-74	Cellular Immune Response in Man	Baylor Univ
(22)	X-75	Basal and Light Activity Metabolism	JSC
(23)	X-76	Monkey Cardiovascular Dynamics	Univ of California/ ARC
(24)	X-77	Urine Electrolyte Determination	JSC

Payload Configuration

Figure 3-8 illustrates the general arrangement of the Life Sciences payload. This view, looking aft in the Spacelab long module, illustrates the key features of the payload. The majority of equipment items are installed in standard Spacelab racks. These divide almost evenly by volume between standard electronic or electro-mechanical units (amplifier, oscilloscopes, spectrometer, etc.) and special bio-science support elements (specimen holding units, surgical workbench, refrigerator, etc.).

In addition to the rack-mounted equipment, significant floor installations are required. The monkey pod installation provides an environmentally controlled chamber for two primates with automatic feeding and water systems and a controlled lower body negative pressure. The rotating base assembly supports either a chair or gimballed platform assembly (normally stowed) and provides for controlled angular rotation or tilt rates.

Considerable volume is required for the stowage of miscellaneous items for the Life Sciences experiments. This includes smaller instruments (centrifuge, microscope) consumables (specimen food/water) surgical supplies, syringes, scissors, etc. Some volume is available in the racks, including consumables. A multitude of smaller items are contained in the overhead stowage.

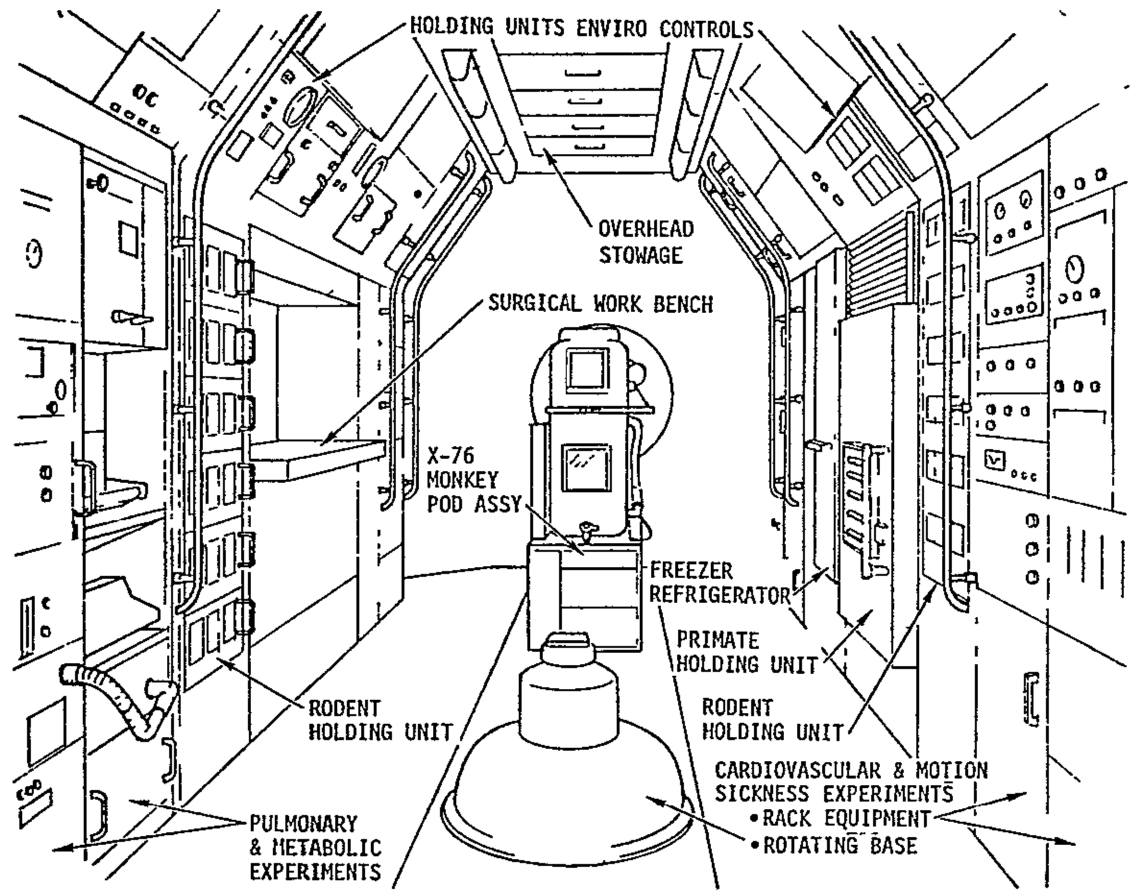


Figure 3-8. Life Sciences General Arrangement

ADVANCED TECHNOLOGY LABORATORY PAYLOAD

The payload used in this study as representative of the multi-disciplined and lab-plus-pallet configuration of the Spacelab traffic model was an Advanced Technology Laboratory (ATL) experiment complement, ATL. This particular payload, ATL, was conceptually designed in the ATL Experiment Systems Definition Study, NAS1-14116. Experiments are located on a two-pallet train, in the short module, on a cradle that spans the Orbiter-Spacelab interconnecting crew access tunnel, and in the Orbiter AFD.

Experiment Complement

The experiments included in the ATL payload are listed in Table 3-4. The complete details of the scientific and technological objectives of each of these experiments is contained in Section 5.0 of Volume I (Representative Payload Definition).

ORIGINAL PAGE IS OF POOR QUALITY

Table 3-4. ATL Payload Experiments

Experiment Number	Description
SF-1	Laser Gyro Navigation
SF-2	Short Manipulator (Teleoperator)
ST-1	Drop Dynamics Module
ST-2	Environment Contamination Monitor
ST-3	Laser Heterodyne Spectrometer
ST-5	Column Density Monitor
ST-10	Microwave Radiometer
ST-16B	Basic Structural Elements (Erectable)
ST-20	Space Calibration of Solar Cells
ST-21	Two-Phase Heat Transfer
ST-25	Combustion Facility
ST-26	Geophysical Fluid Flow
X-2	Attitude Reference Determination System

The resultant integrated payload represents a high-density assembly of diverse activities and equipment types.

Payload Configuration

The Advanced Technology Laboratory payload is illustrated in Figure 3-9. This payload consists of a short Spacelab module and two Spacelab and 12 experiments. Two of these experiments, Basic Structural Elements (ST-16) and Short Manipulator (SF-2), are mounted on a special support structure forward of the module over the crew tunnel.

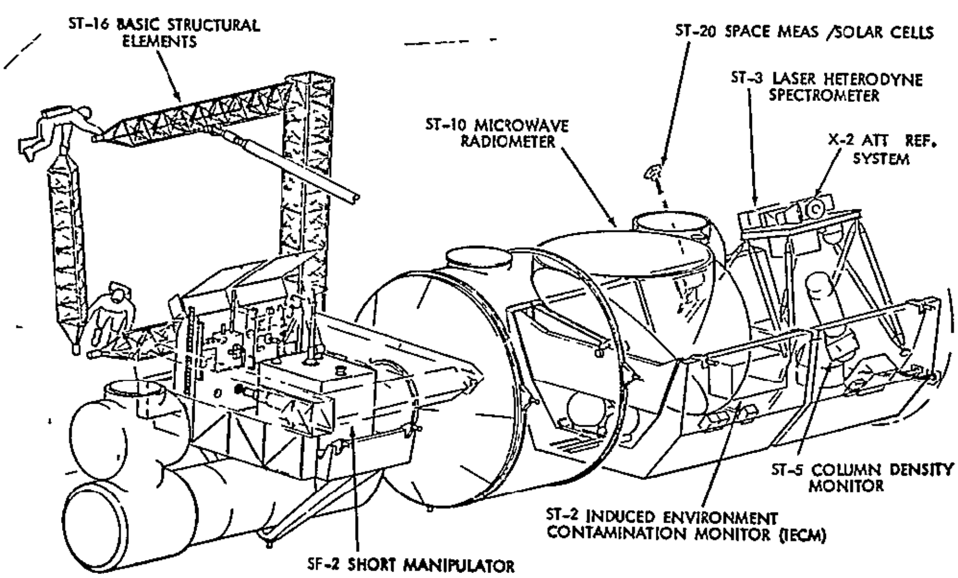


Figure 3-9. ATL Payload General Arrangement

3.3 GROUND PROCESSING REQUIREMENTS AND OPTIMIZATIONS

The ground processing requirements for each of the four representative payloads were determined by establishing the basic experiment installation and checkout requirements, then by defining the sequences in which these components would be installed/assembled. Then the activities of verification were factored into the resource requirements for personnel, equipment, and serial ground processing time. Prior to establishing the payload installation and test requirements, three elements were defined:

(1) Baseline Concept Development Guidelines
(2) Applicable Payload Options
(3) Standardized Task Estimations

A baseline approach to ground processing activities for each payload was established with a set of guidelines/assumptions pertaining to pre-Level IV integration activities as well as Level IV activities. Subsequent system level trades were conducted to determine the cost implications of some of these guidelines. The principle guidelines used are illustrated in Table 3-5.

Table 3-5. Baseline Concept Development Guidelines

NO.	GUIDELINE
1	All Spacelab interfacing hardware and experiment equipment will be in operable condition and ready for installation/integration and the initiation of Level IV activities.
2	The Spacelab interfacing element will be available at the Level IV site. That is, regardless of what the element is (rack, pallet, IPS, SIPS, RAU, EPDB, EPSP, I/C, coldplate, inverter, etc.), it was assumed that it would be available at the Level IV site.
3	Interfacing elements such as RAU's, EPDB's, EPSP's, I/C's, and coldplates will be installed in/on racks and pallets during staging operations at KSC.
4	Interconnections between coldplates on pallets and transition cables/coolant lines on forward pallets will be installed during staging operations at KSC.
5	Integration of instruments/sensors with SIPS canisters is accomplished prior to Level IV activities.
6	Integration of experiment subassemblies that will be installed as a single end item in/on Spacelab mounting elements or payload unique support structure will be accomplished prior to Level IV activities.
7	Where practical, currently defined Spacelab and payload GSE will be used/adopted for Level IV integration activities.
8	In general, checkout activities will consist of verification of installation and interconnection operations. Specification, performance, end-to-end, or calibration tests will be conducted if the installation/interconnection operation affects these parameters.
9	Repetition of a test is required if an interface is interrupted for reasons of transportation or subsequent assembly operations.
10	None of the Spacelab equipment located in the Igloo or subsystem racks of the module are available during Level IV activities.

Based upon the basic processing guidelines and the configurations of the representative payloads, the applicability of the ground processing options to the four payloads was determined. The applicability is summarized in Table 3-6. Note that the pallet only payloads, Combined Astronomy and Space Processing, do not require Level III assembly at KSC. The pallet only payloads required no physical mating of pallets and, therefore, could bypass the Level III assembly at KSC. The other two payloads, Life Sciences and ATL, require Level III assembly at KSC except in those options that include integrated payload assembly and transportation (B-4 and C-4). Options B-4 and C-4 included the combined experiment buildup and integration. The totally assembled and integrated payloads would be transported directly to the Level II stand in the O&C building.

Table 3-6. Options Applicable to Each Payload

PAYLOAD	APPLICABLE OPTIONS	RATIONALE
COMBINED ASTRONOMY	A-2 B-2, B-4 C-2, C-4	LEVEL III ASSEMBLY AT KSC (BLOCK 10) IS NOT REQUIRED FOR THIS PAYLOAD
SPACE PROCESSING	A-2, B-2, B-4 C-2, C-4	LEVEL III ASSEMBLY AT KSC (BLOCK 10) IS NOT REQUIRED FOR THIS PAYLOAD
ADVANCED TECHNOLOGY LABORATORY	A-1, A-3 B-1, B-3, B-5 C-1, C-3	LEVEL III ASSEMBLY AT KSC IS REQUIRED IF INDIVIDUAL EXPERIMENT BUILDUP IS USED (BLOCKS 5 & 6) OR PALLET SEGMENTS ARE DISCONNECTED FOR SHIP (BLOCK 9)
	B-4, C-4	LEVEL III ASSEMBLY IS NOT REQUIRED IF COMBINED EXPERIMENT BUILDUP IS USED, AND PALLET TRAIN IS SHIPPED
LIFE SCIENCES	A-1, A-3 B-1, B-3, B-5 C-1, C-3	LEVEL III ASSEMBLY AT KSC IS REQUIRED IF INDIVIDUAL EXPERIMENT BUILDUP IS USED (BLOCKS 5 & 6) OR RACK/FLOORS FOR BOTH MODULES ARE DISCONNECTED FOR SHIPMENT (BLOCK 9)
	B-4, C-4	LEVEL III ASSEMBLY IS NOT REQUIRED IF COMBINED EXPERIMENT BUILDUP IS USED AND FLOOR SETS ARE DURING BUILDUP.

In order to provide consistency between options and payloads and traceability, the estimates for the accomplishment of Level IV integration tasks were standardized. Four general categories of activity were defined: structural/mechanical installation, cable/harness installation, rigid/fluid line installation, and interface verification.

The structural/mechanical installation methodology example is illustrated in Figure 3-10. Time estimates are for nominal installations. If a major installation such as mounting of the SIRTF on a two-pallet train is involved, then an individual evaluation of the task was conducted. In the case of task estimates for cable harnesses, the activities included in these estimates are final dressing of cable/harness, installation of the harness restraints (P-clamps) and final connection to equipment.

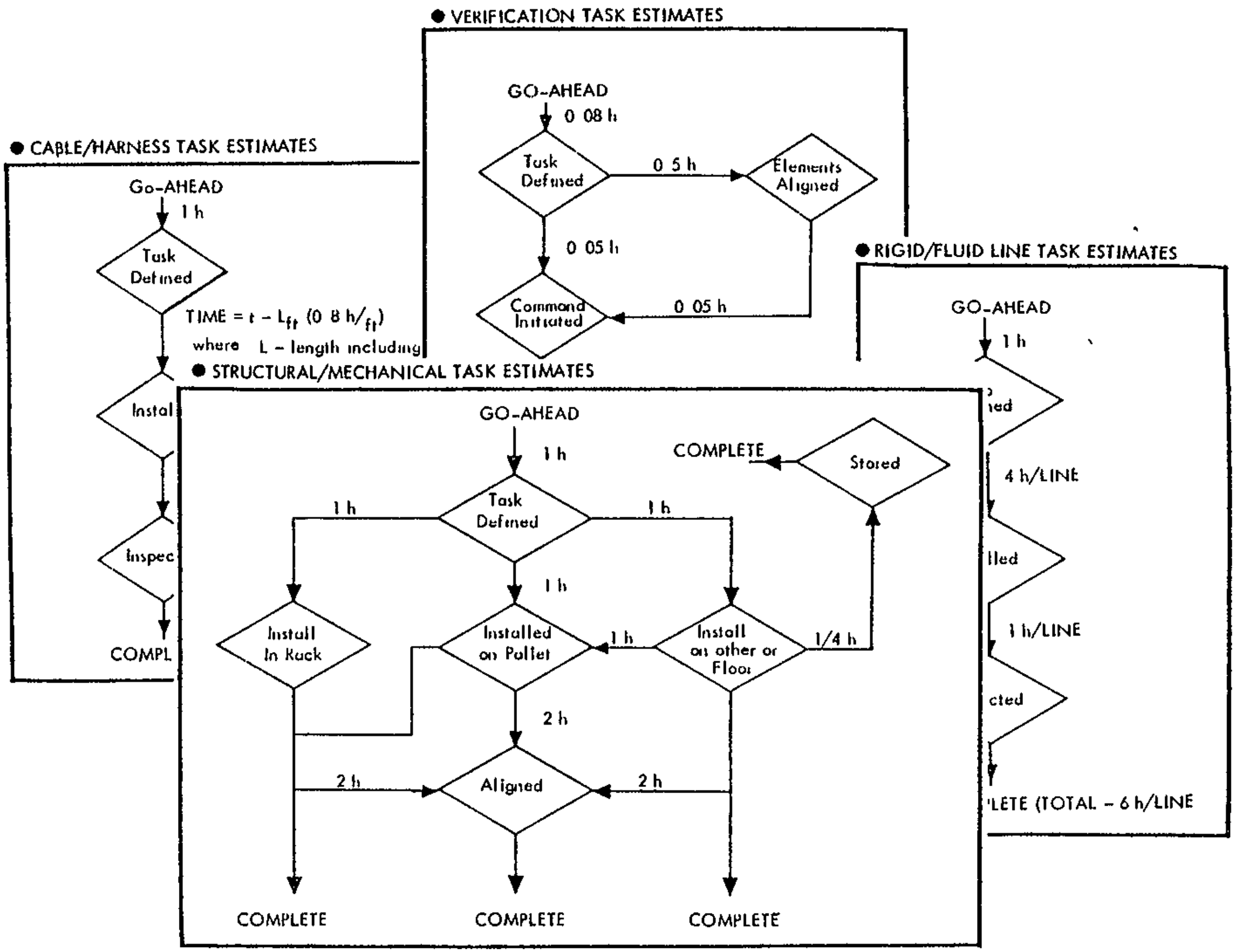


Figure 3-10. Standardized Task Estimation

Space Transportation System
Integration & Operations Division
Space Systems Group

Rockwell International

INSTALLATION AND TEST REQUIREMENTS

For each of the four representative payloads the following factors were defined and evaluated.

- Installation Requirements
  - Experiment Equipment
  - Common Support Equipment
  - Spacelab Unique Equipment
  - Special Handling, C/O, Servicing and Auxiliary Ground Support Equipment

- Test Requirements Identification
  - Pre-Level IV Integration
  - Equipment status at initiation of Level IV Integration
  - Level IV functional testing
    - Software validation

- Assembly procedures

- Installation and Test Sequences

In the area of installation requirements, an analysis was performed of all the experiment end items. For each applicable option the common support equipment, Spacelab unique equipment, and GSE required were established. Basic assumptions were established in the development of the test requirements for the processing of each payload. The more significant groundrules for each payload are presented in the appropriate payload section of Volume II (Ground Processing Requirements).

Buildup sequence illustrations were developed for each of the four referenced payloads. They identify the experiment equipment items to be installed, and includes their buildup status (condition at initiation of Level IV assembly and checkout) as well as the support equipment required. The buildup sequence contains a pictorial step by step illustration of the buildup of the entire payload. The buildup sequences for each payload are presented in Volume II (Ground Processing Requirements).

In addition, step-by-step sequences of installation and the test sequences were developed for the Level IV integration, of each payload, for the applicable ground processing options. Examples of the installation and test sequences for the Combined Astronomy payloads have been included in this volume. The sequences for the A-1, B-1, and C-1 options

are identical. Three separate sequences of activities corresponding to the three complements of the combined astronomy payload are illustrated in Figures 3-11, -12, and -13. For the A-1 option, the sequences would be conducted at three geographically separated locations and require a full complement of GSE at each site. In the B-1 and C-1 options, the same three sequences are applicable, but they would be conducted at a centralized site and at the launch site respectively. Appropriate scheduling/staggering of operations will permit sharing of certain items of GSE even though the three sequences can be conducted separately.

The A-2, B-2, and C-2 Level IV integration sequences are also identical. The basic difference between these options being the location where the integration activities are completed. Transportation between activities and the location vary between options but the basic tasks are the same. In essence, the basic tasks for the three options are completed and then an integrated payload checkout (soft connect-prior to the Level III/II/I KSC-STS operations) is conducted. These integrated payload activities were defined for each payload. The Combined Astronomy example is illustrated in Figure 3-14.

Installation and Test sequences similar to these were defined for each payload and each applicable option. These installation and test sequence waterfalls are defined in detail in the appropriate payload sections of Volume II.

The assembly and checkout of payloads was also evaluated at the integrated payload level. These data reflected the efficiencies that arise from the minimizing of equipment moves and GSE connect/disconnect activities. An example of an integrated payload level assembly and checkout is depicted in Figure 3-15. Note that the total serial processing time for this integration sequence is 126 hours. Figure 3-16 presents a partial example of the installation and test drawing used in the study to visually depict the sequence of installation and testing performed in Level IV. Using the sequence of installation and test tasks developed for the "waterfall" charts, and itemizing these tasks, illustrations of the experiment end items and Spacelab support elements were combined in a flow diagram to aid in visualizing the assembly and test sequence. This provided visual cues for the development of GSE end item requirements and aids in refining and optimizing "hands-on" personnel requirements and task timelines.

LEVEL IV INTEGRATION RESOURCE REQUIREMENTS

Resource requirements for each of the four representative payloads were established from these buildup sequences and the detailed installation and test sequences (waterfalls) presented in Section 3.0, Volume II. The summation of these detail Level IV tasks together with the interaction of Spacelab and STS activities from staging through post-flight integration formed the basis for the establishment of the ground processing resource requirements in the areas of personnel, Spacelab flight hardware, Spacelab unique GSE and Transportation costs. Transportation estimates reflect the variations in inter-intra-site shipment for the various options.

0 10 20 30 40 50 60 70 80 90

- RECEIVE SPACELAB FLIGHT EQUIPMENT WITH SUBSYSTEMS INSTALLED; EXPERIMENT FLIGHT EQUIPMENT, CONSOLES, & SPACELAB/EXPERIMENT/CONSOLE-UNIQUE & COMMON GSE
- TRANSPORT ALL EQUIPMENT TO LEVEL IV WORK AREA OR TO STORAGE AREA(3)
- PERFORM RECEIVING INSPECTION ON ALL EQUIPMENT(8)
- INSTALL UV PHOTOMETER/TELESCOPE(UV/PT) PANEL IN THE PSS PANEL RACK(7)
- INSTALL SMALL INSTRUMENT POINTING SYSTEM(SIPS) PANEL IN THE PSS PANEL RACK(5)
- INSTALL FAR UV SCHMIDT CAMERAS/TELESCOPE PANEL IN PSS PANEL RACK(5)
- CONNECT PSS PANELS TO CB57 AT PORT LEADING EDGE OF PALLET #1(DIRECT SIGNAL CABLES) & TO OPERATORS CONSOLES(S/S & EXPERIMENT I/O UNITS)(4)
- CONNECT OPERATORS CONSOLE TO CB51 AT STARBOARD LEADING EDGE OF PALLET #1(4)
- CONNECT FREON SERVICER(612084A) TO REFRIGERATION UNIT(612115A) & TO S/S FREON LOOP Q/D's AT THE I/F CONNECTOR BRACKET ON PORT LEADING EDGE OF PALLET#1 CONNECT REFRIGERATOR UV TO FACILITY H_2O SERVICE S/S FREON SYSTEM (10)
- CONNECT GROUND POWER CABLE TO THE OPERATORS CONSOLE, TO THE PSS PANEL RACK, & TO THE GROUND POWER SOURCE
- COMMAND SPACELAB SUBSYSTEMS "ON" AT THE OPERATORS CONSOLE(2)

- LOCATE PALLET #1 IN ITS PALLET INTEGRATION POSITION
- HOIST SIPS TO PALLET #1 & LOCATE IN POSITION(4)
- PERFORM ALIGNMENT OF SIPS & TORQUE ATTACH BOLTS TO PALLET #1 PER INSTALLATION DRAWING(8)
- INSTALL HARNESS CONTAINING PC-1(AC), PC-2(DC), SC-1, SC-2 & SC-12 BETWEEN THE SIPS CONTROL ELECTRONICS UNIT & THE EPDB, PALLET #1(PC-1 & PC-2), THE EXPERIMENT RAU(SC-12-SIPS CONTROL), & THE EXPERIMENT INTERCONNECTING STATION(IS)(SC-1-SCHMIDT CONTROL/DATA,SC-1-UV/PT CONTROL/DATA)(5)

- INSTALL UV/PT CANISTER ON THE SIPS(8)
- INSTALL FAR UV SCHMIDT CAMERAS/TELESCOPE CANISTER ON THE SIPS(8)
- CONNECT GN_2 SOURCE TO QD's ON BOTH CANISTERS(3)

- VERIFY LEVEL IV INSTALLATIONS OF THE UV/PT & FAR UV SCHMIDT CAMERAS/TELESCOPE EXPERIMENTS USING PSS PANEL RACK(7)

a. SIPS MAIN POWER CONTROL FUNCTION ON-OFF
b CANISTER LAUNCH/ENTRY LATCH OPERATION
c SIPS OPERATION ABOUT Z AXIS
d SIPS OPERATION ABOUT Y AXIS
e CANISTERS ABOUT YOKE Z AXIS
f JETTISON CIRCUIT INTEGRITY
g CANISTER "A" PURGE PRESSURE
h SIPS SCHMIDT CAMERA DOOR OPEN/CLOSE FUNCTION
i SCHMIDT SYSTEM MAIN POWER ON/OFF FUNCTION
j SCHMIDT SYSTEM CAMERA 1 & 2 ON/OFF FUNCTION
k SCHMIDT SYSTEM TV CAMERAS OPERATING FUNCTION
l SCHMIDT SYSTEM FILM ADVANCE OPERATION
m SCHMIDT SYSTEM DATA RETURN
n CANISTER "B" PURGE PRESSURE
o PHOTOMETER MAIN POWER ON/OFF CONTROL FUNCTION
p CHANNELTRONS (C1 TO C7) & PHOTOMETER (PM-1 TO PM-4) LOW VOLTAGE ON/OFF
q CHANNELTRONS (CT-1 TO CT-7) & PHOTOMETERS (PM-1 TO PM-4) LOW VOLTAGE ON/OFF
r PHOTOMETER MODE CONTROL LOCAL/REMOTE
s PHOTOMETER CALIBRATION SOURCE CT & PM IN/OUT
t PHOTOMETER COMMAND ENABLE/EXECUTE
u PHOTOMETER STAR PRESENCE RELATIVE MAGNITUDE METER
v PHOTOMETER TRACKER LOCK ON/OFF
w PHOTOMETER DETECTOR MALFUNCTION POWER ON/OFF
x PHOTOMETER DETECTOR MALFUNCTION AUDIO SELF/TOT
y PHOTOMETER OPERATION CONTROL FUNCTION

ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME 1

- COMMAND SPACELAB S/S's "OFF" AT THE OPERATORS CONSOLE & DISCONNECT ALL GSE CABLING & FLEX LINES (6)
- REMOVE ALL CONTROL & DISPLAY PANELS FROM THE PSS PANEL RACK & SECURE PANELS FOR SHIPMENT (12)
- SECURE PALLET #1 FOR SHIPMENT(6)

89 HRS

FOLDOUT FRAME 2

Figure 3-11. Combined Astronomy Forward Complement Installation and Test Sequence

0 10 20 30 40 50 60 70 80 90 100 110 HOURS

RECEIVE SPACELAB FLIGHT EQUIPMENT WITH SUBSYSTEMS INSTALLED, EXPERIMENT FLIGHT EQUIPMENT, CONSOLES, & SPACELAB/EXPERIMENT/CONSOLE-UNIQUE & COMMON GSE
TRANSPORT ALL EQUIPMENT TO LEVEL IV WORK AREA OR TO STORAGE AREA (4)
PERFORM RECEIVING INSPECTION OF ALL EQUIPMENT EXCEPT THE SHUTTLE INFRA-RED TELESCOPE (SIRTF)(8)
INSTALL SIRTF PANEL "A" IN THE PSS PANEL RACK(8)
INSTALL SIRTF PANEL "B" IN THE PSS PANEL RACK (6)
INSTALL INSTRUMENT POINTING SYSTEM (IPS) PANEL IN PSS PANEL RACK (4)
CONNECT PSS PANELS TO CB57 AT PORT LEADING EDGE OF PALLET #2 (DIRECT SIGNAL CABLES) & TO OPERATORS CONSOLE (S/S & EXPERIMENT I/O UNITS) (4)
CONNECT OPERATORS CONSOLE TO CB51 AT STARBOARD LEADING EDGE OF PALLET #2 (4)
CONNECT FREON SERVICER (612084A) TO REFRIGERATION UNIT (61215A) & TO S/S FREON LOOP AT CB51 AT THE STARBOARD LEADING EDGE OF PALLET #2. CONNECT REFRIGERATOR UNIT TO FACILITY WATER. SERVICE S/S FREON SYSTEM (10)
CONNECT GSE FLEX FREON LINES TO THE S/S FREON LOOP BETWEEN PALLETS #2 & #3 (5)
CONNECT GSE SIGNAL CABLES BETWEEN PALLETS #2 & #3 (5)
CONNECT GROUND POWER CABLE TO OPERATORS CONSOLE, TO PSS PANELS, & TO GROUND POWER SOURCE. COMMAND SPACELAB SUBSYSTEMS "ON" AT THE OPERATORS CONSOLE (2)

PERFORM RECEIVING INSPECTION OF SIRTF EQUIPMENT - VERIFY TELESCOPE IS EVACUATED (15)
LOCATE PALLETS #3/4 IN THEIR PALLET INTEGRATION POSITION
LOCATE PALLET #2 IN ITS PALLET INTEGRATION POSITION
INSTALL HARNESS CONTAINING SC-6A, SC-7A & SC-8A BETWEEN CB53, PALLET #2, & THE IPS BASE CONNECTOR BRACKET (CB)(4)
INSTALL HARNESS CONTAINING SC-3, SC-4, SC-8B, PC-3B, & PC-4B BETWEEN THE MIC & THE IPS/SIRTF I/F RING CB-(STOW HEATER END FOR LATER CONNECTION) (8)
INSTALL HARNESS CONTAINING PC-3A, & PC-4A BETWEEN EPDB, PALLET #2, & THE IPS BASE CB (5)
INSTALL HARNESS CONTAINING SC-7B & PC-6 BETWEEN THE CRYOGEN TANK HEATER & THE IPS/SIRTF I/F RING CB-(STOW HEATER END FOR LATER CONNECTION) (8)
INSTALL HARNESS CONTAINING SC-6B & PC-8 BETWEEN THE SUNSHADE ACTUATOR & THE IPS/SIRTF I/F RING CB-(STOW SUNSHADE END FOR LATER CONNECTION) (19)
INSTALL HARNESS CONTAINING SC-5 (9HRS) & SC-10 (REMAINING 13 HRS) BETWEEN CB53, PALLET #3 & THE SIRTF ATTACH TRUNNIONS POWER/SIGNAL DISTRIBUTION BOX (SC-5), & THE SIRTF COVER ACTUATORS (SC-10)-(STOW DISTRIBUTION BOX & COVER ENDS FOR LATER CONNECTION (22)
INSTALL HARNESS CONTAINING SC-9 & PC-5 BETWEEN THE SIRTF ATTACH TRUNNIONS POWER/SIGNAL DISTRIBUTION BOX & THE EXPERIMENT RAU, PALLET #4 (SC-9), & THE EPDB, PALLET #4 (PC-5) - (STOW DISTRIBUTION BOX END FOR LATER CONNECTION)(10)
INSTALL PC-7 BETWEEN EPDB, PALLET #4, & THE SIRTF COVER ACTUATORS - (STOW COVER END FOR LATER CONNECTION)(13)
HOIST SIRTF TO PALLETS #3/4 & LOCATE IN POSITION (6)
PERFORM ALIGNMENT OF SIRTF & TORQUE ATTACH BOLTS TO PALLETS #3/4 PER INSTALLATION DRAWING (8)
CONNECT GROUND POWER CABLE TO SIRTF EXTERNAL POWER RECEPTACLE (FOR VACUUM PUMP)(1)
CONNECT ALL CONNECTORS LEFT STOWED PRIOR TO SIRTF INSTALLATION (5)

VERIFY LEVEL IV INSTALLATIONS OF THE SIRTF EXPERIMENT USING THE PSS PANELS (18)

a. SIRTF PANELS A&B MAIN POWER CONTROL
b IPS MAIN POWER CONTROL
c. POWER VOLTAGE AT SIRTF
d TEST COMMAND PROGRAMMED SEQUENCE RECEIVED AT SIRTF
e. TELESCOPE COVER ENGAGE/DISENGAGE LATCHES (SIMULATED)
f. TELESCOPE COVER EXTEND/RETRACT (SIMULATED)
g. TELESCOPE TRUNNION ENGAGE/DISENGAGE (4 PLACES) (SIMULATED)
h. IPS RING - TELESCOPE COUPLING (SIMULATED)
i. CRYOGENIC TANK PRESSURE READOUT
j CRYOGENIC TANK PRESSURE QUANTITY READOUT
k. SUNSHADE EXTEND/RETRACT (SIMULATED)
l. SECOND MIRROR POSITION 1/POSITION 2
m SIRTF INTERNAL CALIBRATION
n. VIDEO INSTRUMENT POINTING SYSTEM CONTROL FUNCTION
o. SUN AVOID ON/OFF FUNCTION
p. SIRTF MODE SWITCH AUTO/MANUAL FUNCTION
q. CRYO FLOW RATE CONTROL FUNCTION
r. CRYO PURGE ON/OFF FUNCTION (SIMULATED)
s. WATER DUMP CONTROL FUNCTION (SIMULATED)
t. VERIFY IPS X, Y & Z CONTROL & RESPONSE (4)

COMMAND SPACELAB S/S's "OFF" AT THE OPERATORS CONSOLE & DISCONNECT ALL GSE CABLING & FLEX LINES (8)
REMOVE ALL CONTROL & DISPLAY PANELS FROM THE PSS PANEL RACK & SECURE FOR SHIPMENT (13)
SECURE PALLETS #2 & #3/4 FOR SHIPMENT (8)

110 HRS

FOLDOUT FRAME /

ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME 2

Figure 3-12. Combined Astronomy Mid-Complement Installation and Test Sequence

0 10 20 30 40 50 60

RECEIVE SPACELAB FLIGHT EQUIPMENT WITH SUBSYSTEMS INSTALLED; EXPERIMENT FLIGHT EQUIPMENT CONSOLES, AND SPACELAB/EXPERIMENT/CONSOLE-UNIQUE & COMMON GS

TRANSPORT ALL EQUIPMENT TO LEVEL IV WORK AREA OR TO STORAGE(5)

PERFORM RECEIVING INSPECTION OF ALL EQUIPMENT EXCEPT THE MEDIUM ENERGY GAMMA RAY DETECTOR (MEGRD) EQUIPMENT(8)

INSTALL MEGRD PANEL IN PSS PANEL RACK(5)

CONNECT OPERATORS CONSOLE TO CB51 AT STARBOARD LEADING EDGE OF PALLET #5(4)

CONNECT PSS PANELS TO CB57 AT PORT LEADING EDGE OF PALLET #5(DIRECT SIGNAL CABLES) & TO OPERATORS CONSOLE(S/S & EXPERIMENT I/O UNITS)(4)

CONNECT FREON SERVICER(612084A) TO REFRIGERATION UNIT(612115A) & TO S/S FREON LOOP AT CB51 ON THE STARBOARD LEADING EDGE OF PALLET #5. CONNECT REFRIGERATION UNIT TO FACILITY WATER. SERVICE S/S FREON SYSTEM(10)

CONNECT GROUND POWER CABLE TO OPERATORS CONSOLE, TO PSS PANELS, & TO GROUND POWER SOURCE COMMAND SPACELAB SUBSYSTEMS "ON" AT THE OPERATORS CONSOLE(2)

PERFORM RECEIVING INSPECTION OF MEGRD EQUIPMENT(16)

LOCATE PALLET #5 IN ITS PALLET INTEGRATION POSITION

INSTALL HARNESS CONTAINING SC-11 & PC-9 BETWEEN EXPERIMENT RAU, PALLET #5(SC-11), & EPDB, PALLET #5(PC-9), & THE MEGRD-(STOW MEGRD ENDS FOR LATER CONNECTION(5)

HOIST MEGRD TO PALLET #5 & LOCATE IN POSITION (6)

PERFORM ALIGNMENT OF MEGRD & TORQUE ATTACH BOLTS TO PALLET #5 PER INSTALLATION DRAWING(4)

CONNECT SC-11 & PC-9 CONNECTORS TO THE MEGRD(2)

VERIFY LEVEL IV INSTALLATIONS OF THE MEGRD EXPERIMENT USING THE PSS PANEL RACK(3)

a COMMAND & DISPLAY PANEL POWER CONTROL FUNCTION
b. POWER TO EXPERIMENT ON/OFF CONTROL FUNCTION
c. HIGH VOLTAGE UPPER & LOWER SPARK CHAMBER CONTROL FUNCTION & POWER VOLTAGE AT EXPERIMENT
d. TIME OF FLIGHT FUNCTION
e. SPARK CHAMBER GAS PRESSURE CONTROL & DISPLAY FUNCTION
f. CRT & KEYBOARD FUNCTION & DISPLAY FOR ITEMS a THROUGH e

FOLDOUT FRAME
2

FOLDOUT FRAME
1

COMMAND SPACELAB SUBSYSTEMS "OFF" AT THE OPERATORS CONSOLE & DISCONNECT ALL GSE CABLING & FLEX LINES(6)

REMOVE MEGRD CONTROL & DISPLAY PANEL FROM PSS PANEL RACK & SECURE FOR SHIPMENT(6)

SECURE PALLET #5 FOR SHIPMENT(4)

58 HRS

Figure 3-13. Combined Astronomy Aft Complement Installation and Test Sequence

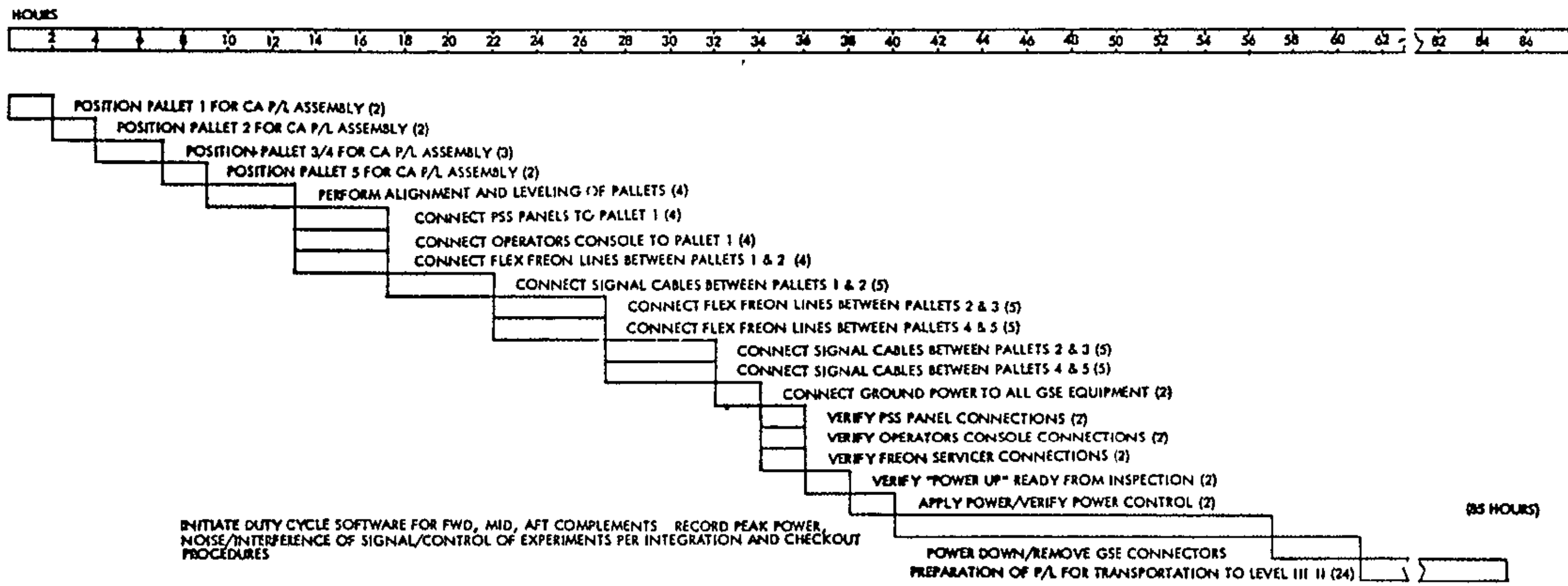


Figure 3-14. Combined Astronomy Combined Payload Assembly and Checkout Sequence

ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME 1

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

RECEIVE SPACELAB FLIGHT EQUIPMENT WITH SUBSYSTEMS INSTALLED; EXPERIMENT FLIGHT EQUIPMENT; CONSOLES; AND SPACELAB/EXPERIMENT/CONSOLE-UNIQUE & COMMON GSE
TRANSPORT ALL EQUIPMENT TO LEVEL IV WORK AREA OR TO STORAGE AREA (3)
PERFORM RECEIVING INSPECTION ON ALL EQUIPMENT EXCEPT THE SHUTTLE INFRARED TELESCOPE FACILITY (SIRTF) AND THE MEDIUM ENERGY GAMMA RAY DETECTOR (MEGRD) (8)
INSTALL SIRTF PANEL "A ON THE PSS PANEL RACK (8)
INSTALL SIRTF PANEL "B ON THE PSS PANEL RACK (6)
INSTALL UV PHOTOMETER/TELESCOPE (UV/PT) PANEL IN THE PSS PANEL RACK (7)
INSTALL SMALL INSTRUMENT POINTING SYSTEM (SIPS) PANEL IN THE PSS PANEL RACK (5)
INSTALL FAR UV SCHMIDT CAMERAS/TELESCOPE PANEL IN PSS PANEL RACK (5)
INSTALL INSTRUMENT POINTING SYSTEM (IPS) PANEL IN PSS PANEL RACK (4)
INSTALL MEGRD PANEL IN PSS PANEL RACK (5)
CONNECT PSS PANELS TO CB57 AT PORT LEADING EDGE OF PALLET #1 (DIRECT SIGNAL CABLES) & TO OPERATORS CONSOLE (S/S & EXPERIMENT I/L UNITS) (4)
CONNECT OPERATORS CONSOLE TO CB81 AT STARBOARD LEADING EDGE OF PALLET #1 (4)
CONNECT GSE FLEX FREON LINES TO THE S/S FREON LOOP BETWEEN PALLETS #1 & #2 (5)
CONNECT GSE SIGNAL CABLES BETWEEN PALLETS #1 & #2 (5)
CONNECT FREON SERVICER (#6120844) TO REFRIGERATION UNIT (#612115A) & TO S/S FREON LOOP Q/D's AT THE I/F CONNECTOR BRACKET ON PORT LEADING EDGE OF PALLET #1 CONNECT REFER. UNIT TO FACILITY H_2O. SERVICE S/S FREON SYSTEM (10)
CONNECT GSE FLEX FREON LINES TO THE S/S FREON LOOP BETWEEN PALLETS #4 & #5 (5)
CONNECT GSE FLEX FREON LINES TO THE S/S FREON LOOP BETWEEN PALLETS #2 & #3 (5)
CONNECT GSE SIGNAL CABLES BETWEEN PALLETS #4 & #5 (5)
CONNECT GSE SIGNAL CABLES BETWEEN PALLETS #2 & #3 (5)
CONNECT GROUND POWER CABLE TO PERIPHERAL EQUIPMENT CONSOLE; TO OPERATORS CONSOLE; TO PSS PANELS; & TO GROUND POWER SOURCE, COMMAND SPACELAB SUBSYSTEMS "ON" AT THE PERIPHERAL EQUIPMENT CONSOLE (2)

PALLET #1

LOCATE PALLET #1 IN ITS PALLET INTEGRATION POSITION

PALLET #2

LOCATE PALLET #2 IN ITS PALLET INTEGRATION POSITION
INSTALL HARNESS CONTAINING SC-6A, SC-7A & SC-8A BETWEEN CB53, PALLET #2, & THE IPS BASE CONNECTOR BRACKET (CB) (4)
INSTALL HARNESS CONTAINING PC-3A, & PC-4A BETWEEN EPDB, PALLET #2 AND THE IPS BASE CB (3)

PALLET #3/4

PERFORM RECEIVING INSPECTION OF SIRTF EQUIPMENT - VERIFY TELESCOPE IS EVACUATED (15)
LOCATE PALLETS #3/4 IN THEIR PALLET INTEGRATION POSITION
INSTALL HARNESS CONTAINING SC-3, SC-4, SC-8B PC-3B, & PC-4B BETWEEN THE MIC & THE IPS/SIRTF I/F RING CB - (STOW MIC END FOR LATER CONNECTION) (6)
INSTALL HARNESS CONTAINING SC-7B & PC-5 BETWEEN THE CRYOGEN TANK HEATER & THE IPS/SIRTF I/F RING CB - (STOW HEATER END FOR LATER CONNECTION) (8)
INSTALL HARNESS CONTAINING SC-6B & PC-6 BETWEEN THE SUNSHADE ACTUATOR & THE IPS/SIRTF I/F RING CB - (STOW SUNSHADE END FOR LATER CONNECTION) (19)
INSTALL HARNESS CONTAINING SC-5 (9 HRS) & SC-10 (REMAINING 13 HRS) BETWEEN CB53, PALLET #3 & THE SIRTF ATTACH TRUNNIONS POWER/SIGNAL DISTRIBUTION BOX (SC-5) AND THE SIRTF COVER ACTUATORS (SC-10) - (STOW DISTRIBUTION BOX & COVER ENDS FOR LATER CONNECTIONS) (22)
INSTALL HARNESS CONTAINING SC-9 & PC-5 BETWEEN THE SIRTF ATTACH TRUNNIONS POWER/SIGNAL DISTRIBUTION BOX & THE EXPERIMENT RAU, PALLET #4 (SC-9), AND THE EPDB, PALLET #4 (PC-5) - (STOW DISTRIBUTION BOX END FOR LATER CONNECTION) (10)
INSTALL PC-7 BETWEEN EPDB, PALLET #4 AND THE SIRTF COVER ACTUATORS - (STOW COVER END FOR LATER CONNECTION) (13)
HOIST SIRTF TO PALLETS #3/4 & LOCATE IN POSITION (6)
PERFORM ALIGNMENT OF SIRTF & TORQUE ATTACH BOLTS TO PALLETS #3/4 PER INSTALLATION DRAWING (8)
CONNECT GROUND POWER CABLE TO SIRTF EXTERNAL POWER RECEPTACLE (FOR VACUUM PUMP) (1)
CONNECT ALL CONNECTORS LEFT STOWED PRIOR TO SIRTF INSTALLATION (5)

PALLET #5

PERFORM RECEIVING INSPECTION OF MEGRD EQUIPMENT (16)
LOCATE PALLET #5 IN ITS PALLET INTEGRATION POSITION
INSTALL HARNESS CONTAINING SC-11 & PC-9 BETWEEN EXPERIMENT RAU, PALLET #5 (SC-11), & EPDB, PALLET #5 (PC-9), & THE MEGRD - (STOW MEGRD ENDS FOR LATER CONNECTIONS (5)
HOIST MEGRD TO PALLET #5 & LOCATE IN POSITION (6)
PERFORM ALIGNMENT OF MEGRD & TORQUE ATTACH BOLTS TO PALLET #5 PER INSTALLATION DRAWING (4
CONNECT SC-11 & PC-9 CONNECTORS TO THE MEGRD (2)

VERIFY LEVEL IV INSTALLATIONS OF THE UV/PT & FAR UV SCHMIDT CAMERAS/TELESCOPE EXPERIMENTS USING PSS PANEL RACK (8)

a SIPS MAIN POWER CONTROL FUNCTION ON-OFF
b CANISTER LAUNCH/ENTRY LATCH OPERATION
c SIPS OPERATION ABOUT Z AXIS
d SIPS OPERATION ABOUT Y AXIS
e CANISTERS ABOUT YOKE Z AXIS
f JETTISON CIRCUIT INTEGRITY
g CANISTER A PURGE PRESSURE
h SIPS SCHMIDT CAMERA DOOR OPEN/CLOSE FUNCTION
i SCHMIDT SYSTEM MAIN POWER ON/OFF FUNCTION
j SCHMIDT SYSTEM CAMERA 1 & 2 ON/OFF FUNCTION
k SCHMIDT SYSTEM TV CAMERAS OPERATING FUNCTION
l SCHMIDT SYSTEM FILM ADVANCE OPERATION
m SCHMIDT SYSTEM DATA RETURN
n CANISTER B PURGE PRESSURE
o PHOTOMETER MAIN POWER ON/OFF CONTROL FUNCTION
p CHANNELTRONS (C1 TO C7) & PHOTOMETER (PM-1 TO PM-4) LOW VOLTAGE ON/OFF
q CHANNELTRONS (CT-1 TO CT-7) & PHOTOMETERS (PM-1 TO PM-4) LOW VOLTAGE ON/OFF
r PHOTOMETER MODE CONTROL LOCAL/REMOTE
s PHOTOMETER CALIBRATION SOURCE CT & PM IN/OUT
t PHOTOMETER COMMAND ENABLE/EXECUTE
u PHOTOMETER STAR PRESENCE RELATIVE MAGNITUDE METER
v PHOTOMETER TRACKER LOCK ON/OFF
w PHOTOMETER DETECTOR MALFUNCTION POWER ON/OFF
x PHOTOMETER DETECTOR MALFUNCTION AUDIO SELF/TOT
y PHOTOMETER OPERATION CONTROL FUNCTION

ORIGINAL PAGE IS OF POOR QUALITY

VERIFY LEVEL IV INSTALLATIONS OF THE SIRTF EXPERIMENT USING THE PSS PANELS (18)

a SIRTF PANELS A&B MAIN POWER CONTROL
b IPS MAIN POWER CONTROL
c POWER VOLTAGE AT SIRTF
d TEST COMMAND PROGRAMMED SEQUENCE RECEIVED AT SIRTF
e TELESCOPE COVER ENGAGE/DISENGAGE LATCHES (SIMULATED)
f TELESCOPE COVER EXTEND/RETRACT (SIMULATED)
g TELESCOPE TRUNNION ENGAGE/DISENGAGE (4 PLACES) (SIMULATED)
h IPS RING - TELESCOPE COUPLING (SIMULATED)
i CRYOGENIC TANK PRESSURE READOUT
j CRYOGENIC TANK PRESSURE QUANTITY READOUT
k SUNSHADE EXTEND/RETRACT (SIMULATED)
l SECOND MIRROR POSITION 1/POSITION 2
m SIRTF INTERNAL CALIBRATION
n VIDEO INSTRUMENT POINTING SYSTEM CONTROL FUNCTION
o SUN AVOID ON/OFF FUNCTION
p SIRTF MODE SWITCH AUTO/MANUAL FUNCTION
q CRYO FLOW RATE CONTROL FUNCTION
r CRYO PURGE ON/OFF FUNCTION (SIMULATED)
s WATER DUMP CONTROL FUNCTION (SIMULATED)
t IPS X, Y & Z CONTROL & RESPONSE (4)

VERIFY LEVEL IV INSTALLATIONS OF THE MEGRD EXPERIMENT USING THE PSS PANEL RACK (3)

a COMMAND & DISPLAY PANEL POWER CONTROL FUNCTION
b POWER TO EXPERIMENT ON/OFF CONTROL FUNCTION
c HIGH VOLTAGE UPPER & LOWER SPARK CHAMBER CONTROL FUNCTION & POWER VOLTAGE AT EXPERIMENT
d TIME OF FLIGHT FUNCTION
e SPARK CHAMBER GAS PRESSURE CONTROL & DISPLAY FUNCTION
f CRT & KEYBOARD FUNCTION & DISPLAY FOR ITEMS a THROUGH e

COMMAND SPACELAB SUBSYSTEMS "OFF" AT THE PERIPHERAL EQUIPMENT CONSOLE & DISCONNECT ALL GSE CABLING & FLEX LINES (12)
REMOVE ALL CONTROL & DISPLAY PANELS FROM THE PSS PANEL RACK & SECURE PANELS FOR SHIPMENT (24)
SECURE PALLET #1 FOR SHIPMENT (4)
SECURE PALLET #5 FOR SHIPMENT (4)
SECURE PALLETS #2 & #3/4 FOR SHIPMENT (8)

126 HRS

REV 1-3-78

FOLDOUT FRAME 2

Figure 3-15. Combined Astronomy Lead Center/KSC

PRECEDING PAGE BLANK NOT FILMED

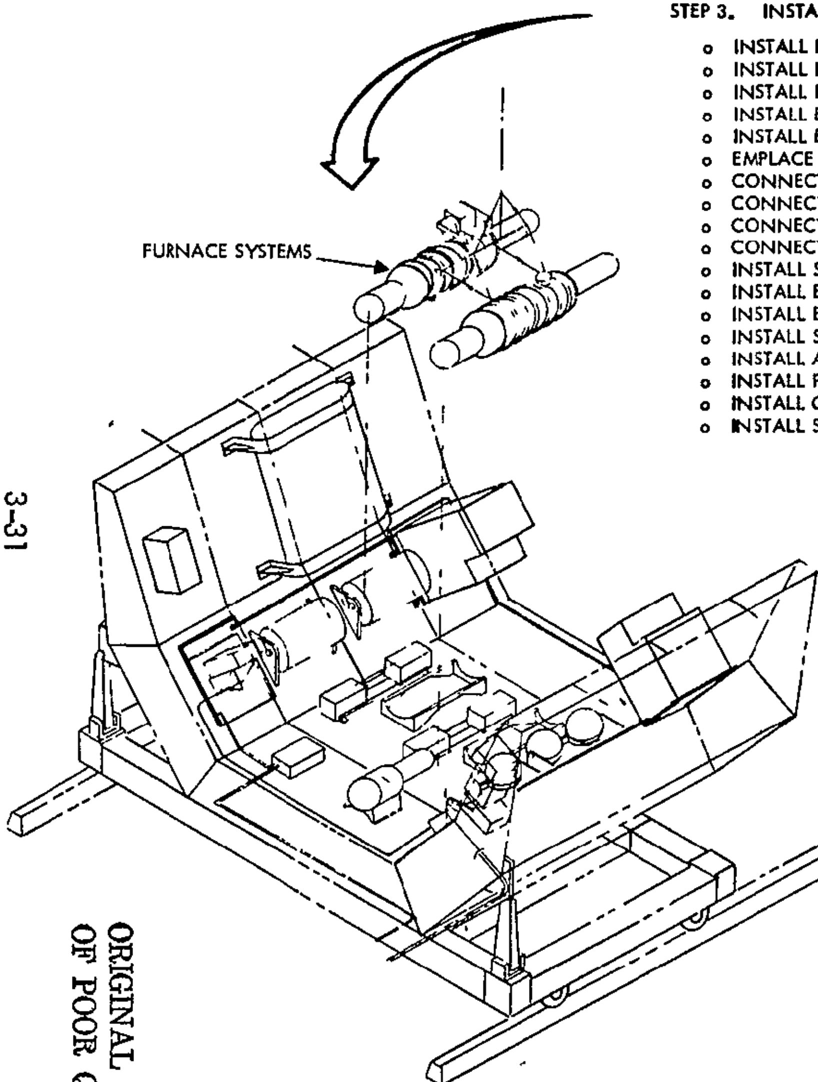
Space Transportation System
Integration & Operations Division
Space Systems Group

Rockwell International

INSTALLATION SEQUENCE

STEP 3. INSTALL FACILITIES #3 & #4 - (EI 3)

- o INSTALL EI-4A ON THE PALLET (3)
- o INSTALL EI-4B ON THE PALLET SIDE WALLS (3)
- o INSTALL EI-4C ON THE PALLET (2)
- o INSTALL EI-5 ON THE S/L COLD PLATE (2)
- o INSTALL EI-2 ON THE PALLET (2)
- o EMPLACE C&W PANEL ON FLOOR (1)
- o CONNECT EMERGENCY COMMAND CABLE FROM R-7 TO EI-4B (1)
- o CONNECT C&W CABLE FROM R-7 TO EI-4A (1)
- o CONNECT STATUS CABLE FROM EI-4A TO RAU (10)
- o CONNECT D/C CABLE FROM EI-4A TO EI-5 (14)
- o INSTALL SUPPORT FOR EI-3 (1)
- o INSTALL EI-3 ON SUPPORT (4)
- o INSTALL EI-
- o INSTALL SI
- o INSTALL AC
- o INSTALL PO
- o INSTALL CO
- o INSTALL SI



TEST AND VERIFICATION REQUIREMENTS

VERIFY:

I. ELECTROMAGNETIC LEVITATION MELT FACILITY INSTALLATION & TEST TIMELINE FOR SPACE PROCESSING FACILITY #1

- o APPLICATION OF POWER AT CONTROL/DISPL
- o TEST SEQUENCE INITIATION AT CDMS DDU (
- o OPERATION OF CHAMBER HEATER, CAMERA, ELECTROMAGNETIC SYSTEM AT CDMS DDU
- o TEST SEQUENCE TERMINATION AT CDMS DDU
- o REMOVAL OF POWER AT CONTROL/DISPLAY P
- o REMOVE GSE POWER AND SIGNAL CABLES (2
- o SECURE ALL ASSEMBLED EQUIPMENT FOR SHI

II. ACOUSTIC-LEVITATION MELT FACILITY INSTALLATION & TEST TIMELINE FOR SPACE PROCESSING FACILITY #2

- o APPLICATION OF POWER TO EI 2 AT CON
- o TEST SEQUENCE INITIATION AT CDMS D
- o OPERATION OF CHAMBER HEATER, AC LOOP, SEQUENCER AND LINK SWIT
- o TEST SEQUENCE TERMINATION AT CD
- o REMOVAL OF POWER FROM CHAMBER E PANEL EI 1 (.25)
- o APPLICATION OF POWER TO EI 3 CHAMB PANEL EI 1 (.25)
- o TEST SEQUENCE INITIATION AT CDMS DD
- o OPERATION OF CHAMBER HEATER, ACOUST LOOP, SEQUENCER AND LIMIT SWITCHES
- o TEST SEQUENCE TERMINATION AT CDMS DD
- o REMOVAL OF POWER FROM CHAMBER EI 3 AT PANEL EI 1 (.25)
- o REMOVE GSE POWER AND SIGNAL CABLES (1.
- o SECURE ALL ASSEMBLED EQUIPMENT FOR SHIP

III. MULTIPURPOSE FURNACE MELT FACILITY INSTALLATION & TEST TIMELINE FOR SPACE PROCESSING FACILITY #3

- o LEAK-FREE GAS AND FREON SYSTEM (8)

Figure 3-16. Installation Drawings and Test/Verification Requirements

ORIGINAL PAGE IS OF POOR QUALITY

Space Transportation System Integration & Operations Division Space Systems Group

Rockwell International

PERSONNEL REQUIREMENTS

Three categories of personnel were considered, hands-on personnel, host-center support, and STS operations support. The hands-on personnel estimates reflect the engineers, technicians and quality assurance personnel that perform the installation, checkout, integration, inspection, etc. with the experiment and Spacelab hardware. Host-center support personnel estimates reflect those engineers and technicians at a lead center or KSC required to assist hands-on personnel in accomplishing the integration activities at an unfamiliar site with unique equipments and support procedures. STS operations support personnel estimates reflect the on-site support of the Level IV integration at KSC during Spacelab and Orbiter integration activities. The hands-on effort associated with STS operations was assumed to be accomplished by KSC personnel and was not included in these estimates. Travel and subsistance costs for personnel to support Level IV integration activities at remote sites and to support STS operations at KSC are a significant factor. Average costs for temporary duty relocation (TDY) are about $75 per day.

TRANSPORTATION REQUIREMENTS

The costs of shipment of Spacelab flight and GSE hardware to/from Level IV integration sites other than at KSC were predicated upon the total number of end items and the width of the shipment. Shipments requiring an outsized carrier - greater than 8 feet in width - required five working days and cost $4000. Standard shipments of 8 foot in width were assumed to require two days and cost $3000. Shipments within the KSC complex were assumed to require one day and cost $1000.

No costs were included for shipment of experiment equipments. It was assumed that these costs would be independent of the processing option because the site of manufacture/assembly of the experiment equipment could be at a vendor, contractor, laboratory, university, etc., and thus, shipment to the integration site would be required in all options.

Distributed site options are the most costly because of the duplication of out-sized carrier shipments. Lead center option costs reflect the feasibility of multiple out-sized elements contained in one shipment. As expected, KSC shipment costs are minimal.

GSE REQUIREMENTS

The GSE end items required for Level IV integration with each of the processing options were identified in detail in Section 3.0 of Volume II (Ground Processing Requirements). The duration of use and prorated costs of these end items is also presented in Section 3.0. The baseline used in the study was that all Level IV Spacelab GSE was stored in a depot at KSC and shipped to each integration site for a Level IV ground processing cycle.

The ground processing task waterfalls were the basis for the establishment of the required period of time for GSE end items. Usage or involvement times of each end item of GSE encompassed pre-flight staging through delivery of the payload for STS operations

(in the O&C building) and post-flight deintegration (removal of experiment equipment from Spacelab mounting elements). Since the intent of these analysis were to establish Level IV ground processing option differences, GSE requirements during STS operations were not included in this study.

The determination of GSE involvement times is illustrated in Figure 3-17.

The actual utilization of each end item of GSE required during the various Level IV ground processing activities is illustrated by the heavy black bars at the left of the figure. The duration of that particular usage is indicated by the length of the bar and also contained in the parenthesis at the end of each usage. The triangles shown on each GSE and item are the shipment times, both to and from KSC. These shipment times do not correlate exactly to the end of the usage of a piece of equipment. They have been grouped into logical units that represent a full (standard van) load that would be transported to KSC for future assignment to another Level IV integration activity. The figures containing the involvement times for each item of GSE in all processing options are contained in Appendix E.

The GSE requirements of each processing option were evaluated based on the following:

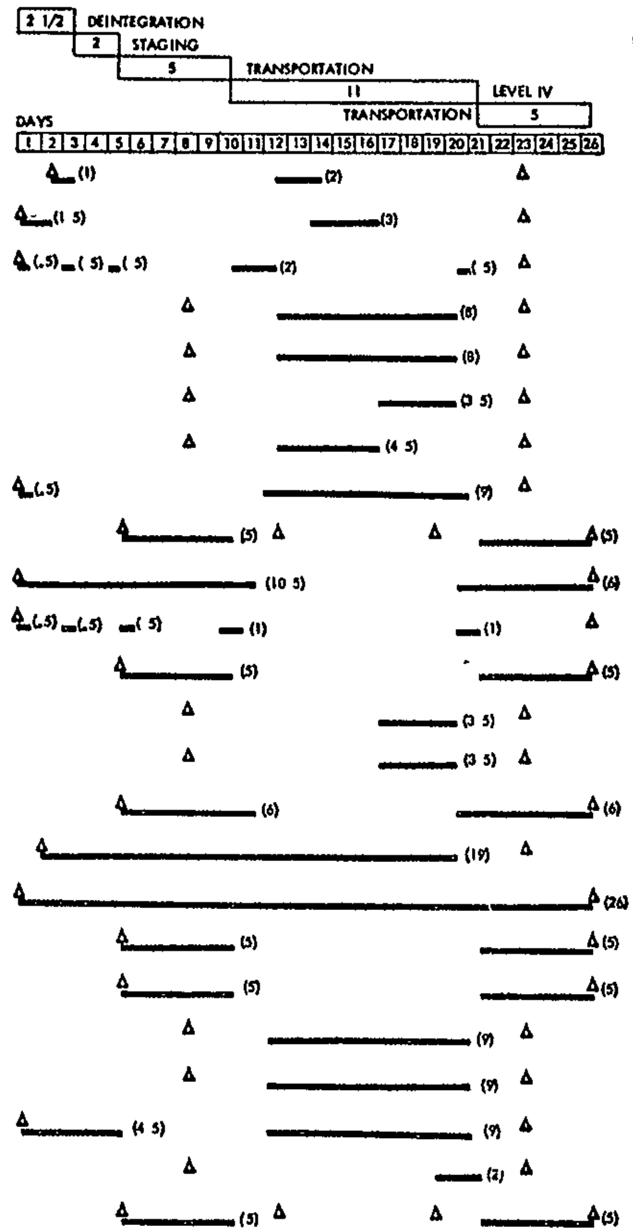
a. Operational processing time for each installation, checkout, shipment, assembly, and disassembly operation.
b. Actual GSE utilization time for each operation.
c. Total GSE involvement time from first Level IV usage or transport of the GSE item to the transport of the GSE item to the next user.
d. Quantity of each GSE item and unit cost.
e. Prorated cost per flight.

Since the GSE under consideration is only that GSE required to support the Level IV operations, those activities associated with Level III/II integration through post-flight operations for each flight are not considered. For GSE the total involvement time consists of the total serial processing time from preparation of experiment and Spacelab equipment through the completion of the Level IV activities and the readiness of the payload to begin Level III (functional block 11) plus the Level IV de-integration operations (functional block 16) after the mission.

SPACELAB FLIGHT HARDWARE REQUIREMENTS

The Spacelab flight hardware requirements for each payload were determined by analyzing the total processing flow times of each option and determining the involvement time of each Spacelab flight hardware end item. The Spacelab flight hardware required for each payload configuration do not vary from one option to another. The real variable is the length of each processing flow. From the determination of total involvement time of the Spacelab flight hardware, a prorated cost per flight was established. The prorated cost per flight was defined by the following

$$\text{Prorated Cost/Flight} = \frac{\text{Involvement Time (days)} \times \text{Unit Cost of Equip. (\$)} \times \text{Quantity}}{250 \text{ days} \times 10 \text{ yr. life}}$$



EQUIPMENT NAME		QTY	UNIT COST ($K)	INVOLVEMENT TIME (DAYS)	PRORATED COST ($)
SLING, SIPS HANDLING	XYZ	1	-	21	-
SLING, CANISTER HANDLING	XYZ	1	-	22	-
SLING KIT, HORIZONTAL-SINGLE PALLET	612110A	1	53,5	22	470 8
RACK SIMULATED OAFD	XYZ	1	1 0	15	-
CONSOLE, OPERATOR	XYZ	1	80,0	15	-
REFRIGERATION UNIT	612115	1	101,0	15	606 0
OPTICAL ALIGNMENT KIT	612040	1	6,0	15	36,0
GN2 SERVICE CART	XYZ	1	50,0	22	440,0
PALLET COVER	612059A	1	12,5	14	70 0
PALLET PLATFORM, SINGLE PALLET	612060A	1	24,0	26	249 6
TRUNNION HOLDING FITTINGS	612113A	4	1 0	26	41 6
TRANSPORTATION INSTRUMENTATION	614XXX	1	20,0	21	168 0
FREON SERVICER	612084	1	25,0	15	150,0
FREON LEAK DETECTOR	612086	1	1,0	15	6,0
FEED THROUGH PROTECTIVE COVER KITS	612008A	1	3,0	21	25,2
PALLET SEGMENT FLOOR COVERS	612010A	1	3,5	21	29 4
PALLET SEGMENT SUPPORT	612013B	1	47,0	26	488,8
DESICCANT CANISTER, LARGE	612067A	1	11,5	21	96 6
ROAD TIEDOWN KIT, U.S.	612106A	1	10,5	21	88,2
GROUNDING/BONDING TESTER	613039	1	31,0	15	186,0
CABLE SETS & ADAPTERS	613XXX	1	1,5	15	-
CLEANING KIT	612114A	1	11,5	21	96,6
DESICCANT DRYING OVEN	614022	1	27,5	15	165.
ACTIVE ENVIRONMENTAL CONTROL CART	612071A	1	33,2	14	185 9

Figure 3-17. Determination of GSE Involvement Times

ORIGINAL PAGE IS
OF POOR QUALITY

The Spacelab flight hardware items evaluated were each payloads requirements for:

- Racks (Expmt)
- Pallet Segment
- RAU's
- EPDB's
- ICS's
- Cold Plates
- IPS
- SIPS
- Inverters
- Freon Pumps
- Expmt Heat Exchangers
- EPSP's
- Floor Segments

PAYLOAD COST SUMMARIES

These summaries have been developed, for each viable option of the four design reference missions, by an accumulation of the per flight costs in each of the four resource categories·

- Manpower
- Transportation
- GSE
- Spacelab Flight Hardware

It should be noted that these following costs are prorated per flight cost and are representative of the major groundrules and guidelines established in the previous sections of this volume. They are intended to provide a reference for the comparison of the 12 major processing options being analyzed as a part of this study. The programmatic cost summaries of these four payloads is discussed in detail in Section 3.4 Programmatic Costing.

Space Processing Ground Processing Cost Summary

The manpower difference with the distributed site options A-1 ($119 K) and A-2 ($123 K) relates to added costs for the additional integrated payload checkout performed at KSC. Because of the unique size of the payload (single pallet) and the relatively short duration of the integrated checkout (2 days) at KSC, the increased manpower costs are only $3,800 for manpower (122,820 option A-2 and $119,020 option A-1) and $445 for TDY ($20,887 option A-2 and $20,662 option A-1). The same factors are found in the options of the other two concepts (B- centralized and C - Launch Site). The manpower differences between concepts, although slight, reflects the host center support variations.

The ground processing costs (prorated) for the Space Processing payload (not including KSC operational costs) from the initiation of Level IV processing through post-flight deintegration are summarized in Table 3-7, as "Total Costs Per Flight".

Transport and hardware proration estimates for the distributed (A-X) and centralized (B-X) options are identical because only one pallet segment is involved. The involvment time for the KSC (C-X) options are less because of shorter transportation times. Thus, prorated hardware costs are also correspondingly less.

Table 3-7. Space Processing Ground Processing Costs
(Costs in $K)

Option	Cost Category					Total Costs Per Flight
	M/P	TDY	XPort	GSE	Flt Hdwe	
A1	119	21	15	6	104	265
A2	123	21	15	o	104	269
B1	124	28	15	6	104	277
B2	128	28	15	6	104	281
B4	128	28	15	6	104	281
C1	130	43	4	4	92	273
C2	·134	44	4	4	92	277
C4	134	44	4	4	92	277

Combined Astronomy Ground Processing Cost Summary

The ground processing costs for the Combined Astronomy payload are summarized in Table 3-8. As with the Space Processing payload summary, these costs are "per mission" fixed costs. The personnel and TDY costs represent the estimates of manpower required to accomplish the tasks of the waterfalls developed for each applicable option. The GSE and Spacelab flight hardware costs are prorated values for the time during which these end items would be supporting some portion of the ground activities for the payload being evaluated. The ranges in fixed costs per flight are relatively equal for all concepts being analyzed - Distributed $224,000 (A-2 to A-1), Centralized $230,000 (B-2 to B-1), and Launch Site $232,000 (C-2 to C-1). The three lowest cost options are C-1 ($840,000), B-1, and A-1 ($909,000). The differences in costs within concepts are due to the lack of pre-Level III/II combined payload checkout in the A-2, B-2, and C-2 options. The C-4 and B-4 options have combined payload checkouts, and these two options are only $19,000 and $32,000 higher, respectively.

Table 3-8. Combined Astronomy Ground Processing Cost Summary (Costs in $K)

Option	Cost Category					Total Costs Per Flight
	M/P	TDY	Xport	GSE	Flt Hdwr	
A-1	167	20	42	14	666	909
A-2	207	32	45	16	833	1133
B-1	174	26	22	8	679	909
B-2	201	35	22	12	869	1139
B-4	170	37	22	10	702	941
C-1	180	62	3	5	509	840
C-2	213	67	3	9	780	1072
C-4	176	60	3	7	613	859

Life Science Ground Processing Cost Summary

The compilation of similar ground processing costs (illustrated in Table 3-9) for the Life Science payload indicates that manpower costs for the multiple (8-mini-centers) distributed site approach will be higher than if individual experiments were integrated at a centralized site. Improved efficiency in hands-on activities can be achieved at a centralized site for rack/floor mounted equipment. The inverse relationship of TDY and transportation costs is again evident.

GSE prorated costs are relatively low. Multiple GSE equipment requirements are reflected in the A-X options. Flight hardware prorations again reflect variations in involvement times.

The option A-2 manpower costs are $30K per mission higher than A-1 because this option has the combined payload checkout at KSC following the individual experiment installation and checkout at each distributed site.

Table 3-9. Life Science Ground Processing Costs
(Costs in $K)

Option	Cost Category					Total Costs Per Flight
	M/P	TDY	Xport	GSE	Flt Hdwr	
A-1	193	22	70	17	67	369
A-3	212	31	70	19	74	406
B-1	163	34	17	6	82	302
B-3	178	36	17	7	91	329
B-4	158	35	17	8	86	304
B-5	169	33	17	9	90	318
C-1	169	53	3	5	73	303
C-3	187	57	3	6	79	332
C-4	168	56	3	6	76	309

ATL Ground Processing Cost Summary

The Advanced Technology Laboratory payload cost compilation (shown in Table 3-10) indicates characteristics very similar to the Life Science payload compilation. Efficiencies can be achieved by centralizing integration activities. TDY, transportation, and hardware proration characteristics also parallel the Life Science payload characteristics.

Table 3-10. ATL Ground Processing Costs (Costs in $K)

Option	Cost Category					Total Costs Per Flight
	M/P	TDY	Xport	GSE	Flt Hdwe	
A-1	194	31	34	10	227	496
A-3	224	41	34	10	243	552
B-1	200	39	14	7	243	503
B-3	209	40	14	8	256	527
B-4	202	49	14	8	256	529
B-5	212	50	14	8	268	552
C-1	206	58	3	5	218	490
C-3	223	60	3	6	231	523
C-4	209	76	3	6	231	525

SYSTEM TRADES

Three special trade studies were conducted to determine the most cost-effective approach for each of the ground processing concepts developed for the representative payloads. These trades included the use of simulated or substituted Spacelab unique equipment for such items as RAU's, IPS, SIPS, Spacelab module floor, cabling, pallet freon pump and the inverter. Use of dedicated Spacelab unique equipment and Shared Spacelab Equipment Utilization were also evaluated in the trades.

Substituted Spacelab Equipment Utilization

The baseline Ground Processing sequences and cost data are based on the assumption that all the Spacelab equipment, with the exception of the Igloo and the Spacelab Module shell, are available at the Level IV integration site. An alternate approach was analyzed wherein the use of simulated or substitute Spacelab equipment was used to determine if savings in overall costs would offset the added costs of the substitute equipment.

The following criteria were established for the selection of candidate Spacelab equipment which could or should be substituted or simulated:

a) High Capital Cost
b) Low Utilization in Level IV
c) Low Risk for Deferred Verification

During the development of the above criteria, it became evident that additional criteria could be developed to exclude equipment from substitution or simulation:

a) Spacelab Subsystem Equipment Not Available in Level IV
b) Spacelab Equipment Required in Level IV

As a result of the application of the criteria discussed above, the primary candidates for substitution are listed in Figure 3-18. IPS and SIPS were evaluated because of their capital costs and minimal applicability during Level IV integration. As both systems are designed for zero-G operations, only minimal interface compatibility between their systems and experiment hardware can be verified in Level IV. Simulations of performance/functional interfaces must be accomplished during the experiment development phase. (Note: SIPS canister integration was considered to be a Level V activity.)

Substitution of floors, cables and fluid lines are inter-related. The assessment addressed the relative costs of the two approaches. However, a primary consideration is the risk factor involved in deferrment of interface verification of cabling and fluid line routing and interconnections until schedule critical III/II activities at KSC.

SUPPORT EQUIPMENT ITEM / PAYLOAD	IPS	SIPS	FLOORS	CABLES	FLUID LINES	FREON PUMP	400 Hz INVERTER
ATL-A	-	-	X	X	X	X	X
COMBINED ASTRONOMY	X	X	-	X	X	X	X
SPACE PROCESSING	-	-	-	X	X	X	X
LIFE SCIENCES	-	-	X	X	-	-	X

- FREON PUMP AND INVERTER
- FLUID LINES
- FLOORS AND CABLES
- IPS
- SIPS (EXAMPLE)

	INCREASE	DECREASE
MANPOWER		
INSTALLATION & REMOVAL OF CANNISTERS FROM SIMULATED SIPS	9,400	
REDUCED DEINTEGRATION		600
TDY		
PI SUPPORT DURING SIPS/CANNISTER INTEGRATION AT KSC	3,200	
TRANSPORTATION		
SHIP TO/FROM LEVEL IV SITE (WIDE LOAD)		8,000
STANDARD SHIPMENT	6,000	
INTRA-SITE MOVES	2,000	
GSE	170	
SUBSTITUTE GSE		3,600
SPACELAB GSE (PALLET HANDLING & SERVICING)		1,440
SIPS GSE		
FLIGHT HARDWARE		
SIPS		9,600
PALLET EQUIPMENT		31,220
CANNISTERS		1,260
	20,770	55,720

NET SAVINGS
$34,950

Figure 3-18. Candidates for Substitution

Space Transportation System
Integration & Operations Division
Space Systems Group
Rockwell International

The freon pump and inverter on the forward or lead pallet segment appeared to be non-essential during Level IV activities. The functions provided by these units had to be simulated for other pallet segments/trains of the pallet. Also, external servicing equipment required to interface with the freon pump could perform the same functions of the pump.

The SIPS example indicates the factors considered in the development of the costs and savings associated with the substitution trades.

The additional task of installing/removing the canisters on a simulated SIPS yoke as a fit check for both mechanical alignment and cable harness alignment was considered. Post-flight deintegration time can also be reduced if SIPS remains on a pallet segment. TDY support increased to reflect the additional support during the added Level III assembly activities at KSC (Block 10).

Transportation costs deltas reflect the elimination of wide-load carriers. A substitute SIPS yoke (pro-rated) was synthesized. The involvement time of the GSE associated with the SIPS and its pallet will be reduced; and thus, a pro-rated cost reduction results. Similarly, flight hardware pro-ration costs are reduced because of the reduction in involvement times. For this example, a net savings of $35K can be achieved by deferring the use of the flight SIPS to Level III-KSC activities.

Conclusions and Recommendations

As a result of the foregoing analyses, the following conclusions and recommendations are presented.

(a) SIPS Substitution - Substitution is indicated and recommended on the basis of the significant cost savings. Saving per mission of $19,000 to $52,000.

(b) IPS Substitution - Substitution is indicated and recommended, again on the basis of even greater cost savings to be realized. Savings per mission of $247,000 to $340,000.

(c) Module Floor Substitution - Substitution is not recommended, based on the additional cost, rather than savings, being realized.

(d) Rack Cabling Substitution - Substitution is not recommended, since the added cost of fabricating and installing GSE cabling ($40,000 to $45,000) appears to be excessive compared with the speculative savings in wear and tear on the flight cables.

(e) Freon Pump and Inverter Substitution - Substitution of GSE supplies of 400 Hz power and Freon coolant is recommended, based primarily on the reduction in operating time on these rather sensitive items of flight equipment. The cost factor ($3,000) favors this approach also, though not significantly.

(f) Remote Access Unit (RAU) Substitution - Substitution of RAU simulators for flight units is not recommended. The savings are insignificant in view of the potential risk incurred from deferring RAU installation and checkout of flight data interfaces.

DEDICATED SPACELAB EQUIPMENT UTILIZATION

The effects of dedicating selected pieces of Spacelab equipment to specific experiments were explored and analyzed. Certain savings in time and manpower can accrue from such an approach. Not only is the time and manpower needed to de-integrate the experimental hardware after flight eliminated but also the time and manpower required to re-integrate the same equipment. The reduction in involvement time of the GSE used, the reduced TDY expenses for integration personnel and benefits of reducing the total processing time are also to be considered.

There are, of course, cost increases associated with dedication due to under-utilization of flight hardware.

Candidate Selection

The four payloads were reviewed, experiment end item by end item, to determine those which most probably would show operational and financial benefit from dedicating Spacelab hardware to the end item(s) in question. This screening consisted of completing a questionnaire for each experiment and end item. The questions considered were as follows:

(1) Is the equipment designed for multiple use?

(2) Is the experiment one which requires frequent reflight to get meaningful data?

(3) Is the equipment of a type which is very difficult and expensive to install and/or adjust at Level IV integration?

(4) Does the equipment occupy a minimal amount of Spacelab equipment (i.e., one rack rather than 5 racks)?

(5) Is the equipment especially sensitive to wear-and-tear damage from repeated integration?

(6) Is the equipment one which must be flown on short lead time such that delay from the integration process is undesireable?

(7) Is the equipment such that the confidence level of success would be significantly higher if Level IV integration were not performed repeatedly?

(8) Can the experiment objectives be met if the equipment is left installed in the Spacelab hardware?

Following review of each experiment end item and completion of the referenced questionnaire, a "Dedication Candidate Rationale" sheet was completed. This sheet recaps the "Yes" factors for each end item of the payload, and allows for recording and consideration of additional factors not covered in the questionnaire and usually unique to the payload end item or experiment being considered. The total factors favoring dedication are then considered and a decision made on whether or not all or part of the experiment should be considered a strong candidate for Spacelab hardware dedication. No specific weighting factors are applied to any of the factors, but a degree of subjective weighting was applied in accordance with the factor evaluation/descriptions above, with question 3 receiving the greatest weight.

Dedication Candidates

After exercising the selection rationale and procedure discussed above, the following candidates for dedication were selected.

Space Processing: Pallet 1 dedicated to Facilities 3 and 4.

Combined Astronomy: Pallet 1 - dedicated to experiments AS-05 and UV-2.

Pallet 3/4 - dedicated to AS-01-S (SIRTF).

Advanced Technology: Pallet 1 - dedicated to experiment ST-10.

Racks 5, 6 and Floor Assembly - dedicated to ST-25 (Combustion Facility).

Life Sciences: Racks 11, 12 and Floor Assembly - dedicated to experiment X-76.

Dedication Cost Analysis - Ground Processing

In order to determine the effect of dedication on the detailed Installation and Test Sequence in Level IV integration, the baseline I&T "waterfall" charts were reviewed. In this review, those steps which would not have to be reperformed if the dedication were in effect, were identified. Only installation steps were so identified; it was assumed that a full sequence of experiment and payload level testing would still be performed. Some steps were eliminated and others shortened or modified in this review. The manpower associated with the modified or deleted steps was tallied, and the effect on total processing time calculated.

To obtain the manpower savings attendant to dedication for the de-integration sequence, the "Waterfall" charts for that sequence were also reviewed in the same manner as the Installation and Test charts, and revised sequence charts constructed.

The results of these revisions were factored into the baseline manpower tables to derive new personnel costs. An example is presented in Table 3-11.

Table 3-11. Combined Astronomy, Dedicated Pallet 1
(Cost in 1977 $)

Cost Element / Concept	A2	B2	B4	C2	C4
MANPOWER					
Installation and Experiment Test, Direct Labor (3,4,5,6)	114120	114120	86360	114120	86360
Payload Testing, Direct Labor (7,8,9)	34460	33190	24940	33190	24940
Installation & Test Support (3 thru 9)	5880	7140	6160	14280	12320
Level III/II/I Integration and Post Flight Support (11, 12, 13, 15)	25920	25920	25920	25920	25920
Deintegration, Direct Labor (16)	8350	8350	8350	8350	8350
Deintegration Support (16)	1680	1680	1680	1680	1680
TOTAL MANPOWER	190410	190400	153410	197540	159570
TDY EXPENSE					
Installation and Exp. Test, Direct Labor	4425	10111	12336	38475	24675
Payload Testing, Direct Labor	12975	6150	4800	12300	9600
Level III/II/I Integration and Post Flight Support	9000	9000	9000	9000	9000
Deintegration, Direct Labor	1950	1950	1950	1950	1950
TOTAL TDY	28350	27211	28086	61725	45225
TRANSPORTATION					
To/From Level IV	44500	22000	22000	3000	3000
GSE PRORATION	17065	14781	12663	12840	10974
TOTAL	280326	254392	216129	275105	218769

Dedication Cost Analysis - GSE Utilization

To determine the effect of Spacelab hardware dedication on the cost of GSE, GSE Utilization/Involvement Time charts were prepared as they were for baseline cost estimation. For the dedicated case, however, the effects of dedication were introduced. The total GSE prorated costs were then calculated based on unit cost and involvement time, as they were for the baseline costs.

Table 3-12 presents an example of these data for GSE requirements.

Table 3-12. Combined Astronomy, Pallet 1 Dedicated Option A1/A2

GSE REQUIREMENTS-COMBINED ASTRONOMY Location Mini-Center Option A1/A2

Quantity	Equipment Name		Unit Cost ($)	Invlvm't Time (Days)	Prorated Cost/Flt($)
0	Vertical Sling Kit	612006	10.5	—	—
1	Feed Thru Protective Covers	612008	3.0	15	18 00
1	Pallet Segment Floor Covers	612010	3.5	15	21.00
1	Pallet Segment Support-Single	612013	47.0	15	282.00
0	Pallet Segment Support-Double	612013	—	—	—
1	Pallet Cover	612059	12 5	15	75.00
1	Pallet Platform-Single Pallet	612060	24.0	15	144.00
0	Pallet Platform-Double Pallet	612060	—	—	—
0	Rack, PSS Panel	612XXX	—	—	—
1	Desiccant Canister-Large	612067	11.5	15	69 00
1	Active Environmental Control Cart	612071	33.0	15	199 20
1	Road Transport Tie Down Kit	612106	10.5	15	63.00
1	Horizontal Sling Kit	612110	53.5	15	321 00
4	Trunnion Handling Fittings	612113	1.0	15	6.00
1	Transportation Instrumentation	614XXX	20.0	15	120.00
1	Optical Alignment Kit	612040	6.0	9	21.60
0	IPS Test and Checkout Kit	612208	120.0	—	—
0	Continuity Tester	613038	90.5	—	—
0	Ground/Bonding Tester	613039	31.0	—	—
0	Portable Leak Detector	612080	2.5	—	—
1	Freon Servicer	612084	25.0	9	90.00
1	Cable Sets and Adapters	613XXX	1 5/cable	9	5.40
1	Freon Leak Detector	612086	1.0	9	3 60
1	Operator's Console	612XXX	80.0	—	—
0	Refrigeration Unit	612115	101.1	9	363.60
1	GN-2 Service Cart	612XXX	50.0	9	180 00
0	Vacuum Pumping Unit	612XXX	25.0	—	—
1	Cleaning Kit	612XXX	11.5	9	41.40
1	Desiccant Drying Oven	614022	27 5	9	99.00
	TOTAL				2122.80

Dedication Cost Analysis - Transportation

No changes in transportation costs were found as a result of dedication.

ORIGINAL PAGE IS
OF POOR QUALITY

Dedication Trade Options

In the previous sections, the methods of determining the basic cost differences between utilization of experiment equipment and Spacelab Flight hardware in a dedicated manner have been explained. These next three sections deal with three alternate methods of utilizing dedication·

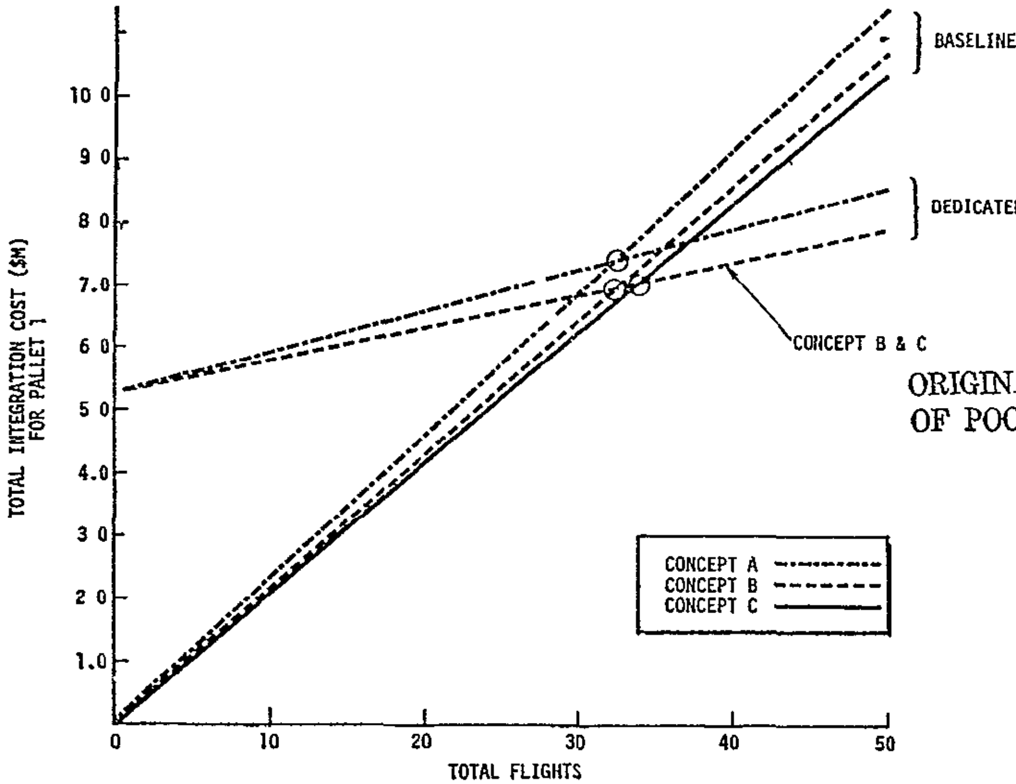
(1) Purchased Equipment Approach - In this option, the User (PI) would purchase the Spacelab flight hardware and would have exclusive use of this equipment for the entire Spacelab program. He could fly his payload at any rate he desired (or at the rate dictated by space available), and between flights the Spacelab equipment would be left stored, with his experiment equipment installed. The basic question in the option is "How many flights must be made before this approach is more economical and cost effective than leasing the equipment from NASA?"

(2) Leasing with Concentrated Flight Schedule - In this option, the PI does not buy the Spacelab equipment, but leases it for a limited period of time. During this period, he flies all the missions needed for his project on a rapid turnaround basis (heads to tails), with no deintegration or reintegration required. Upon completion of the last flight of the project, the Spacelab equipment is returned to NASA for further utilization. This option evaluates the question "What is the magnitude of saving over the baseline (for 10, 20, 30 flights) to dedicated equipment and fly a consecutive rapid turnaround schedule?"

(3) Short Term Lease Approach - In this option, the PI leases the Spacelab equipment for a specific period - one year. During that year, he can fly as few or as many times as he requires. The maximum amount of flights are a function of the time required to process and integrate the payload. This analysis addresses the question "What is the <u>minimum</u> number of flights required to make this approach more economical than the baseline approach?" The following sections are a summary of the results of these options.

Dedication Break-Even Analysis - Purchased Equipment Approach

The results of this analysis for the Combined Astronomy dedicated pallet 1 candidate are illustrated in Figure 3-19. The breakeven points are shown to be in the area of 31-32 flights.



ORIGINAL PAGE IS OF POOR QUALITY

Figure 3-19. Dedicated Spacelab Equipment
Combined Astronomy Dedicated Pallet 1

For the baseline approach, the average integration cost per flight was $228K (Concept A), $215K (Concept B), and $209K (Concept C). For the dedicated examples, the cost of integration was $65.7K (Concept A) and $52.4K (Concepts B and C). These values were then added to the $5,309,000 cost of the Combined Astronomy Pallet #1 and its associated flight hardware listed:

Combined Astronomy - Pallet 1

1 Pallet	$3,022,000
1 SIPS with canisters	1,500,000
3 RAU's	429,000
2 interconnect stations	6,000
1 EPDB	88,000
1 Freon Pump/Accumulator Package	110,000
1 AC Inverter	100,000
2 Coldplates	54,000
Total Cost	$5,309,000

The total costs of the Spacelab flight hardware for the Orbiter candidates are:

. Combined Astronomy - Pallets 3 and 4	\$6,305,000
. Life Sciences - Racks 11, 12, and Floor	651,000
. ATL Payload - Racks 5, 6 and Floor	703,000
. ATL Payload - Pallet 1	\$4,876,000
. Space Processing - Pallet	\$3,724,000

The breakeven points of Figure 3-19 can be calculated by having the average cost per flight of integration for the baseline approach and the dedicated approach and applying them to the equation

Cost of S/L Flt Hdwr + Dedicated Avg Cost of Integ (X) = Baseline Avg Cost of Integ (X)

(where X = the required number of Spacelab flights).

For example, if the cost of the Spacelab flight hardware were \$5.3M and the dedicated average cost of integration were \$80K and the baseline integration costs were \$250K per mission, the breakeven point would be

$$\$5.3M + .08\,(X) = .25(X)$$
$$\$5.3M = .17(X)$$
$$31.2 = X$$

Therefore, it would require 32 flights for the breakeven to occur.

The following table, Table 3-13, lists the breakeven points for each concept of the six candidates for dedication.

Table 3-13. Breakeven Points for Dedication Candidates

Dedication Candidate	Breakeven Pt. Concept A	Breakeven Pt. Concept B	Breakeven Pt. Concept C
Combined Astronomy - Pallet 1	32.7	32.5	33.9
Combined Astronomy - Pallet 3 and 4	30.0	31.2	32.8
Life Science - Racks 11, 12 and Floor	13.8	16.3	16.8
Advanced Technology Lab - Racks 5, 6 and Floor	22.5	20.8	20.4
Advanced Technology Lab - Pallet 1	29.8	27.9	31.8
Space Processing Pallet	19.6	19.2	19.0

The curves and backup data for each of these candidates is covered in detail in Volume III, Optimization and Programmatics.

Dedicated Analysis - Leasing With Concentrated Flight Schedule

This approach assumes that the other elements of the payload (other racks, pallets, etc.) are already fully installed and checked out on the experiment level before the dedicated item is available for integration. Therefore, the Level IV tasks included in the Total Ground Processing time include only (a) Receiving inspection of the pallet or rack, which has just returned from a flight, been deintegrated from the payload, and moved to the integration site, (b) installation of experiment equipment not dedicated to that pallet/rack, (c) experiment level verification, (d) payload inter-connection, payload checkout and disassembly for shipment, where these functional blocks apply. From this point on, the flow returns to the baseline flow except for an abbreviated deintegration operation as in the "dedicated buy" approach.

In order to compare the costs of this dedication approach with the baseline costs of integrating the same hardware/experiments, the data were plotted against baseline data. The plot of total integration costs (for the dedicated hardware only) against total flights of the project shows the amount of savings to be realized from this approach. Also, due to the reduction in total ground processing time in the dedicated case, the number of flights that can be made in a year is increased, and this is shown as well.

Figure 3-20 illustrates the cost comparisons between the baseline and a dedicated leasing with concentrated flight schedule for the Combined Astronomy payload pallet #2. This example is indicative of the results of the dedicated trade for all six candidates. The detail data on each candidate are presented in Volume III, Optimization and Programmatics.

Dedication Analysis - Short Term Lease Approach

In this approach, the Principal Investigator leases rather than buys the Spacelab equipment into which he integrates his experiment hardware. However, in this case the lease is assumed to be for a period of one year. During that year, he can fly as few or as many times as he wishes, within the maximum limits imposed as a result of the involvement time required to integrate and process the payload. He may have a limited time between flights to analyze data from the previous flight. The analysis then addresses the question "What is the minimum number of flights required to make this approach more economical than the baseline approach?"

Although the concept is basically a one year lease, it can be extended to longer lease periods. This would result in increased savings over the baseline approach. Since the ground processing flow is based on the same dedication elements as in the previous approaches, and since the same assumption is made with regard to other payload elements already being integrated before availability of the dedicated element, as with the "Concentrated Lease" approach described previously, the same manpower and TDY figures as used in that section will apply in this approach.

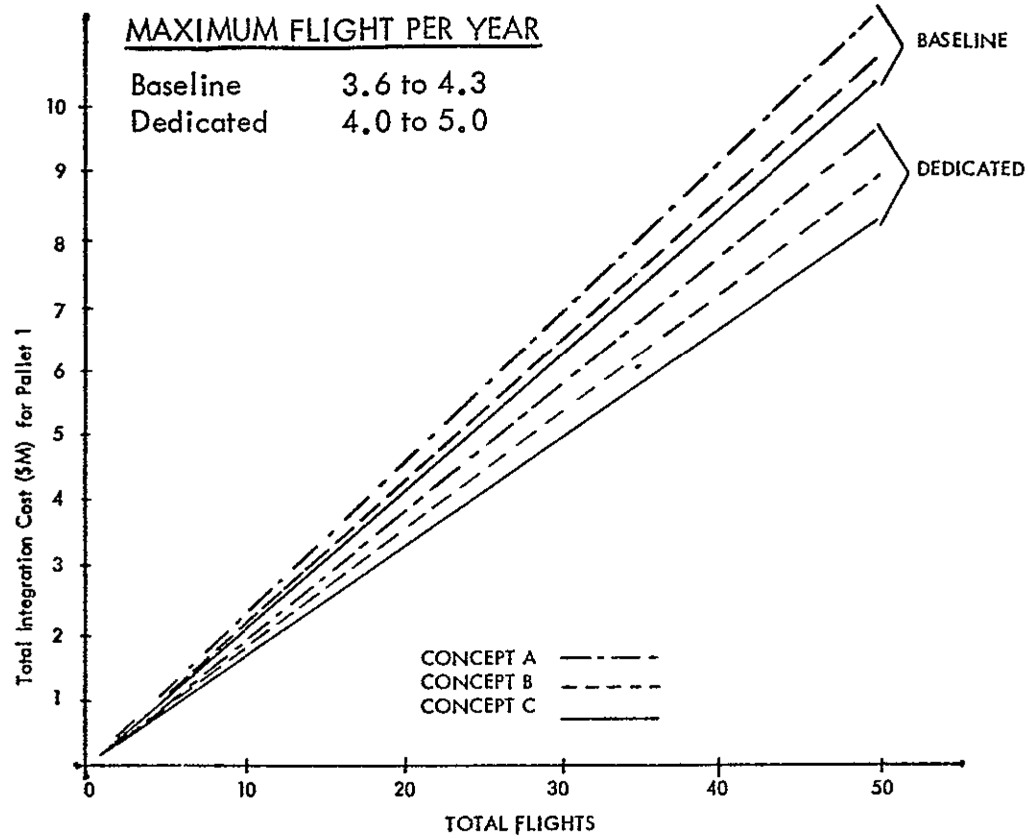


Figure 3-20. Dedicated Spacelab Equipment - Combined Astronomy Dedicated Leased Pallet 1

In the case of the Short Term Lease, the GSE involvement times are the same as they were for the Concentrated Lease and so the GSE costs per flight are also the same. Hence the figures used in the Concentrated Lease section are still applicable and are used in this approach as well. The baseline transportation costs are not changed by this or any other dedication approach, hence the baseline costs attributable to the dedicated payload element are again used in costing this dedication approach.

The cost of the Spacelab Flight Equipment per flight in this approach is calculated on a per-flight basis, for the dedicated elements only.

In this approach, since the Short Term Lease is based on a one-year period, an "annual cost" is calculated as 1/10 of the total equipment cost. This figure was then divided by the number of flights to be carried out during the year, up to the limit imposed by the involvement time required per flight.

Cost Comparison Charts

The data for the Combined Astronomy Pallet 1 candidate is displayed graphically in Figure 3-21, comparing the baseline and dedicated cost totals as a function of flight rate for the year-long lease.

The baseline cost is, of course, a constant per-flight cost for each option. The options are averaged to yield a combined "A", "B", and "C" curves as was done previously. To get the per-flight cost in the dedicated case, the fixed cost subtotal (averaged for the letter option) was added to the flight hardware cost for each flight rate point, and the total plotted. The maximum flight rates are shown as "barriers" at the end of each solid plot line, and the intercepts of the baseline and dedicated plots are marked with small circles. These represent the flight rate at which the total integration cost FOR THE DEDICATED ELEMENT OF THE PAYLOAD is the same whether dedicated or undedicated, and can be considered a "break even" point beyond which the dedicated approach is the most cost effective.

Since, in most cases, the break even point occurs at a non-integer flight rate (which is impossible in a one-year span), cost savings per flight and total are shown for the next integral flight rate. In some cases this requires extrapolation of the curve beyond the maximum flight rate barrier. This is not truly a fallacy since such scheduling devices as using 16-hour work days instead of 8-hour days could shorten the involvement time making such a flight rate possible.

A similar set of curves for all options are discussed in detail in Volume III, Optimization and Programmatics. Table 3-14 contains the breakeven points (flights) and the per mission and total savings for all six dedication candidates.

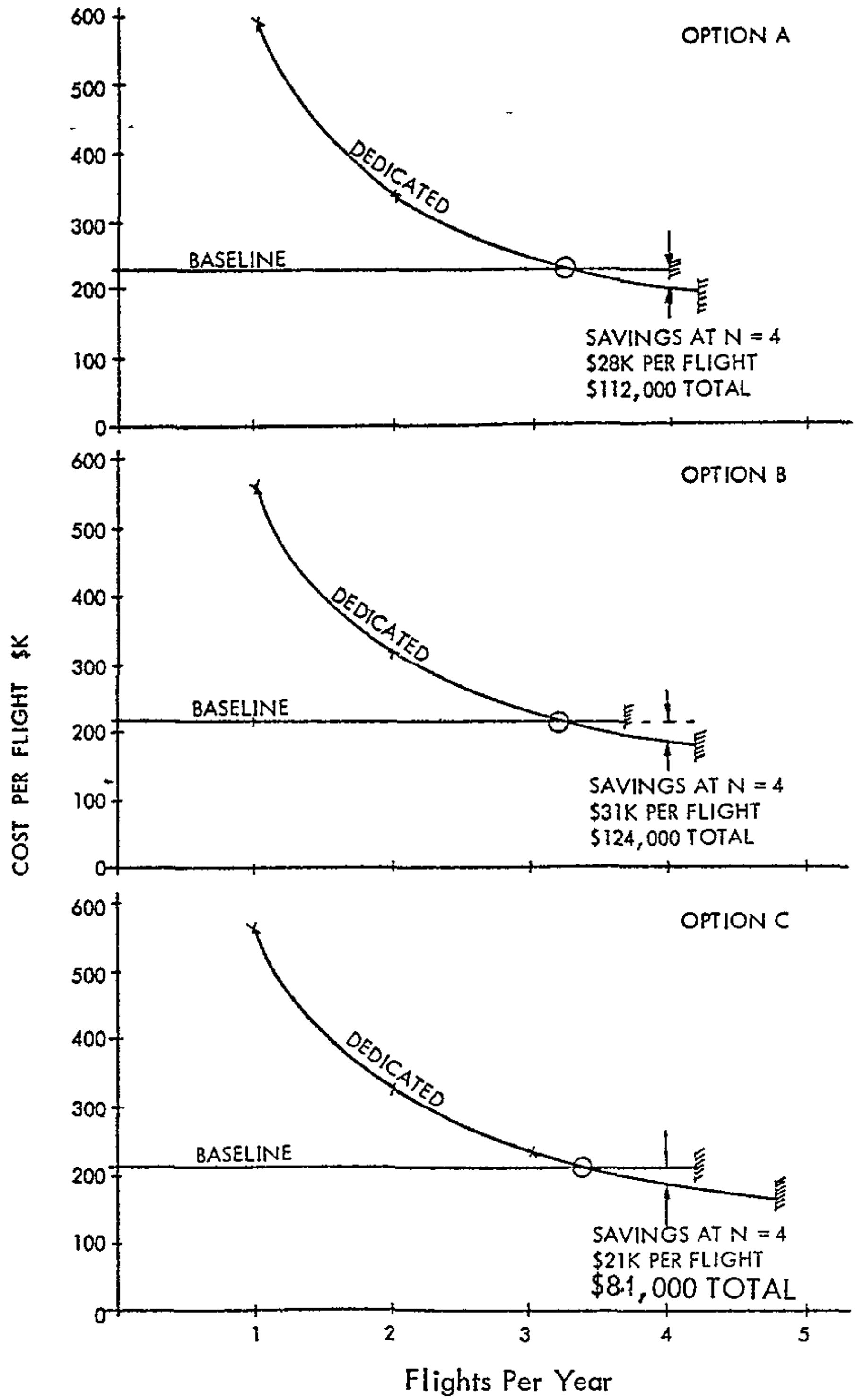


Figure 3-21. Short Lease Dedication
Combined Astronomy-Pallet 1 Dedicated

Table 3-14. Short Term Lease Breakeven Points and Resultant Savings

CANDIDATE	BREAKEVEN PT. N = FLTS	SAVINGS PER FLT	TOTAL	GROUND PROC OPTION
• COMBINED ASTRONOMY PALLET 1	4 4 4	28K 31K 21K	112K 124K 84K	A B C
• COMBINED ASTRONOMY PALLET 3/4	4 4 4	44K 33K 19K	176K 132K 76K	A B C
• LIFE SCIENCE - RACKS 11, 12 & FLOOR	3 3 3	12K 5K 3K	36K 15K 9K	A B C
• ADVANCED TECHNOLOGY LABORATORY - RACKS 5, 6 & FLOOR	2 3 2	3K 12K 4K	6K 36K 8K	A B C
• ADVANCED TECHNOLOGY LABORATORY - PALLET 1	4 3 4	33K 10K 30K	132K 30K 120K	A B C
• SPACE PROCESSING PALLET	2 2 2	22K 28K 29K	44K 56K 58K	A B C

Conclusions and Recommendations

In exploring and analyzing the various ways in which Spacelab flight equipment might be dedicated, it has been seen that dedication is feasible and cost effective in many, but not all, cases. Under any of the dedication approaches, a relatively frequent flight rate is necessary to justify dedication.

A comparison of the three basic dedication approaches would not be valid, since each approach has to be considered in the light of the planned flight schedule, project duration, and financial implications. For example, a university or research center planning to fly a series of astronomical flights with a SIRTF over a long period of time, at a flight rate of twice a year, would be best advised to use the purchase approach. An industrial user planning to manufacture semiconductor crystals in the Space Processing facility at a maximum capacity for a year, following which a major change in equipment would be necessary allowing a slower flight rate for the same production, would probably benefit from the short lease approach followed by a nondedicated lease arrangement. Hence, a user considering dedication would first determine which dedication arrangement

best fit his plans, and then determine if this arrangement would be cost effective at the flight rate he planned to follow.

A review of the conclusions that might be drawn from each approach would be beneficial in determining patterns leading to general guidelines for dedication.

Dedicated Buy Approach - Conclusions

Reviewing the break-even charts in this approach, several conclusions can be drawn. First, the effects of dedication are approximately the same regardless of whether Concepts A, B or C are being followed. Secondly, it can be seen that a rather extensive flight schedule is required for the savings from dedication to offset the capital investment cost. This is particularly true for pallet payloads which involve much more expensive flight equipment. The pallet payloads require on the order of 30 flights (except Space Processing) to pay off - the equivalent of 3 flights per year for the entire program. Space Processing takes less time because of very high cost savings realized from dedication. Rack payloads, on the other hand, require only 15 to 20 flights to pay off and are therefore better candidates for this form of dedication.

Dedicated Lease with Concentrated Flight Schedule - Conclusions

In this approach, a review of the cost comparison charts reveals that a savings can be realized in all cases, regardless of flight rate, but of course since a concentrated launch schedule is presupposed, this approach is unapplicable unless multiple flights on a tight schedule are planned. The savings are less than dramatic (except for Space Processing as explained above) until a large number of flights are reached. In this approach, the difference between pallet payloads and rack payloads is much less apparent, because the flight hardware cost becomes less of a factor when it is based on proration rather than amortization.

Dedicated Short Term Lease - Conclusions

The data for this approach, where full utilization is not presupposed as it was in the Dedicated Lease with Concentrated Flights Schedule, involves a break-even situation again as we saw in the dedicated buy approach. The savings from dedication are weighed against the cost of underutilized hardware, and at a certain flight rate for the one year lease period, savings may be realized. The most significant conclusion evident from these break-even charts is that, as with the dedicated buy approach, rack payloads exhibit quicker and more dramatic savings than do pallet payloads. This, again, is due to the predominant effect of flight hardware cost in an underutilization situation as we see here. Again, Space Processing proves itself to be an exception because of the very significant integration/deintegration savings and somewhat lower pallet costs from the other pallet payloads. With the exception of Space Processing, pallet payloads appear to exhibit cost savings at 80% to 90% utilization while rack payloads exhibit savings at only 50 or 60% utilization.

Shared Spacelab Equipment Utilization

General

The objectives of this sub-task were to determine costs and schedule implications of shared Spacelab equipment utilization through progressive Level IV integration of shared Spacelab hardware. This shared hardware included Spacelab unique equipment such as racks, pallet segments, RAU's, and common support equipment (recorders, IPS, telescopes, chambers, etc.) and GSE.

"Progressive Level IV checkout flows" were developed and compared against baseline Level IV checkout flows to form the basis for analyzing manpower requirements, cost data and use(involvement) times for selected GSE. (A "progressive checkout flow" is one which moves the equipment and personnel from one principal investigator's facility to another in the Level IV progressive build up, assembly and checkout of payload equipment for specific missions.)

Certain assumptions were made for purposes of this analysis.

a) All Spacelab Equipment will be staged (stored, refurbished) at KSC

b) GSE and Spacelab Equipment moves with the payload

c) GSE and Spacelab Equipment moves progressively to each Principal Investigator's Site

d) The involvement time for GSE is based on a dedication rule, that is, once the equipment has been selected for use, even on an intermittent basis, for a particular mission, it will be dedicated to that task for the entire mission period.

Advanced Technology Laboratory (ATL)

Mini Centers are logical experiment/Spacelab flight hardware groupings for a payload. In the case of the ATL payload, there were three mini centers defined. Mini Center 1 group of equipment consisted of the floor, Pallet 1 and Racks 5 and 6. Mini Center 2 consisted of Racks 3a and 3b. Mini Center 3 contained Pallet 2, Racks 4a and 4b, and the forward experiment structure that was mounted over the Spacelab tunnel. Similar logical groupings were made for each payload. The description of the Experiment/Spacelab equipment contained in each mini center, for each payload, are described in Section 2.0, System Trade Studies, of Volume III of this report.

Mini-Center No. 1 progressive flow utilizes 260 hours compared to 128 for the baseline. Mini-Center No. 2 utilizes 112 hours for the progressive compared to 63 hours for the baseline. Mini-Center No. 3 indicated 538 hours are required for the progressive compared to 152 hours for the baseline.

Combined Astronomy

Progressive flows for the three cases were compared with the baseline flows. Case 1 initiates Level IV activity from a common timeline for the forward, mid and aft pallet complements. Only the forward complement was cycled from one site to another for experiment integration. Estimates indicated costs of $291,200 and 138 serial hours for this progressive case as compared to $89,120 and 58 serial hours for the baseline. Case 1 utilized three sets of GSE. Case II initiates forward and aft pallet Level IV activities at the same time. The mid pallet complement Level IV activity was scheduled such that the aft pallet Level IV GSE equipment could be used for the mid pallet complement integration activities. The flow times are about the same as Case 1. In Case III, the forward, mid and aft pallet activities were scheduled such that only one set of checkout and servicing GSE was required. However, the involvement times for the flow increased to 501 serial hours.

Space Processing

Space Processing utilizes only one pallet. The equipment is assigned to experiment categories designated facilities. Facility 1 for example, includes experiment S9A, S9B, and S21. Facility 1 is processed at Site No. 12. The Space Processing payload progresses from Site 12 through Site 16. Site 13 is used to process Experiment CG5 and Site 14 is used to process Experiment CG7, together they constitute Facility No. 2.

The pallet for Space Processing is shipped to five different sites for Level IV integration activities. The serial time to accomplish this would be 595 hours, compared to 119 hours for the baseline.

Life Sciences

Life Sciences, for purposes of this study, has been subdivided into equipment groupings called mini-centers. Eight mini-centers have been selected. Of these eight mini-centers, three were selected for purposes of comparison between the progressive concept and the baseline for Level IV integration. Mini-Center No. 1 consists of Rack No. 3 and the associated floor section. Mini-Center No. 2 consists of Rack No. 4 and Mini-Center No. 6 consists of Rack No. 9. The experiments contained in the racks are listed in the Life Science Matrix listed in Volume I of this report.

The results of this study yielded the following comparison between progressive and baseline processing times.

Mini-Center	Baseline (Hrs)	Progressive (Hrs)
1	142	287
2	94	170
3	83	83
4	78	78
5	55	55
6	90	142
7	90	90
8	208	208
Overall	208	287

Summary

The results of the comparisons of progressive flows and baseline flows for all payloads are presented in Table 3-15. The results are expressed in thousands of 1977 dollars for each option evaluated for each payload. The delta over the baseline option is positive in all cases. This signifies that while the progressive integration minimizes GSE requirements and PI and support personnel TDY, these savings are overshadowed by the increase in transportation and the reduced support capability, for other missions, of the Spacelab flight hardware. For example, in Case III for Combined Astronomy, a delta of $276,000 is shown. This case represents the minimum sets of GSE and checkout equipment and the maximum serial checkout time. The involvement time required for the GSE and flight hardware as well as transportation costs contribute to increase the total cost higher than the baseline.

Table 3-15. Summary of Progressive Trades Cost Data

(K $)	OPTION	MANPOWER	TDY	GSE	SL FLT HARDWARE	TRANSPORTATION	TOTAL $/FLT	BASELINE	DELTA OVER BASELINE
COMBINED ASTRONOMY	A-2								
	CASE I	218	13	23	1,141	45	1,440	1,348	92
	CASE II	218	13	22	1,175	39	1,467	1,348	119
	CASE III	218	13	25	1,252	116	1,624	1,348	276
LIFE SCIENCES	A-1	224	41	21	73	83	442	389	53
	A-3	243	44	22	80	83	472	422	50
SPACE PROCESSING	A-2	114	9	10	166	28	327	249	78
ADVANCED TECHNOLOGY LAB	A-3	205	3	25	328	75	636	559	77

(all costs in thousands of 1977 $)

3.4 PROGRAMMATIC COSTING

In this portion of the study, the per mission resource requirements data pertaining to the four representative payloads were extrapolated to the entire Spacelab traffic model. The schedules and inventory of Spacelab flight hardware and Level IV integration GSE required to support the traffic models were identified.

A preliminary categorization of payloads and a traffic model equivalency has been established. Through this equivalency, a distribution of the resource requirements for the four design reference missions to three traffic models: a Baseline (297 flights), a 2/3 Baseline (199 flights), and a 1/3 Baseline traffic model (99 flights) has been established. Figure 3-22 shows the activities conducted to establish the program resource requirements.

The resource requirements of Personnel, Spacelab flight hardware, GSE and transportation have been established for each of six Level IV ground processing options and within the framework of each of the three traffic models. Summaries of these data are presented in this section.

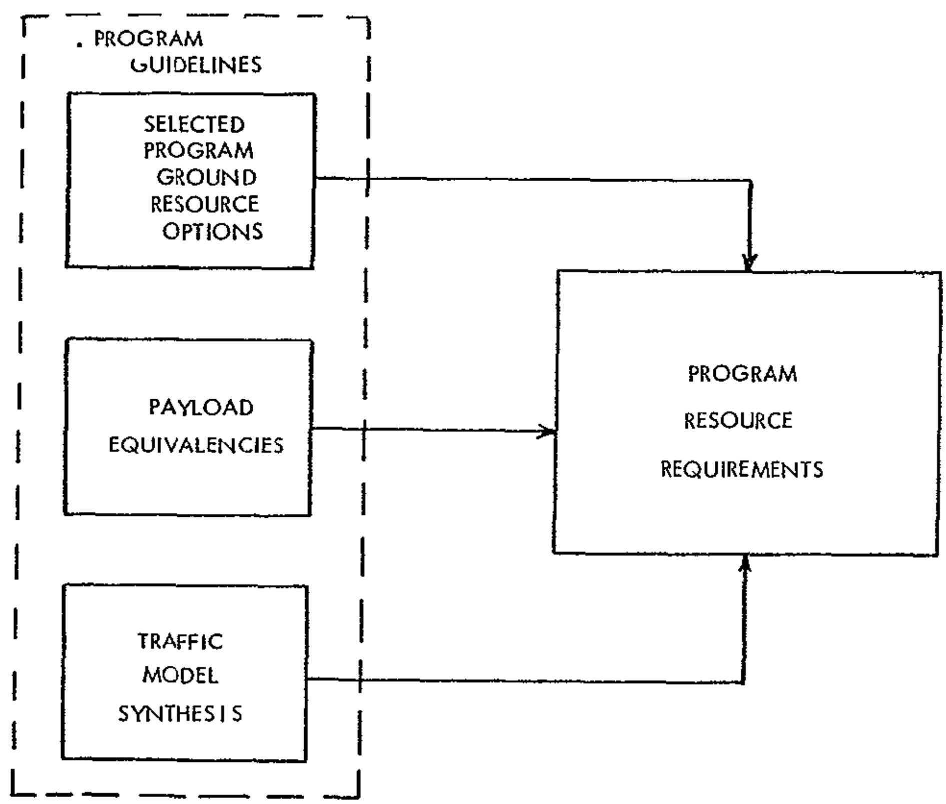


Figure 3-22. Spacelab Level IV Programmatic Assessment

PROGRAMMATIC GUIDELINES

A set of basic programmatic guidelines, illustrated in Table 3-16, used in the programmatic analyses were developed. These guidelines established the relationships between the payload equivalency model, the mission traffic model, the launch schedule, the learning curve, and the cost estimating. The guidelines were used in the (1) rationale for selection of 6 options studied in detail, (2) ground processing time buildup analysis, and (3) schedule analysis for developing payload launch dates. The Payload Equivalency establishes the relationship between the 4 representative payloads and the entire Spacelab traffic model. The Mission Models are the baseline "560" traffic model and the constructed 2/3 and 1/3 models. The Launch Schedule identifies equally spaced launches of pallet only/habitable module alternate configurations. An 80% Learning Curve was used for ground processing times (first 5 flights or 2 years). In Cost Estimating, all resources were estimated in 1977 dollars with inflation rates compounded at the rate of 10% per year for European supplied equipment and 7% per year for all other resources.

Table 3-16. Programmatic Guidelines

• PAYLOAD EQUIVALENCY	- ESTABLISHED RELATIONSHIPS BETWEEN THE FOUR REPRESENTATIVE PAYLOADS AND THE ENTIRE SPACELAB TRAFFIC MODEL
• MISSION MODELS	- - "560" TRAFFIC MODEL USED AS BASELINE - 2/3 AND 1/3 BASELINE MODELS CONSTRUCTED
• LAUNCH SCHEDULE	- EQUALLY SPACED, ALTERNATE CONFIGURATIONS (PALLET ONLY/HABITABLE MODULE)
• LEARNING CURVE	- 80% LEARNING CURVE USED FOR GROUND PROCESSING TIMES (FIRST FIVE FLIGHTS OR TWO YEARS)
• COST ESTIMATING	- ALL RESOURCES ESTIMATED IN 1977 DOLLARS INFLATION RATES COMPOUNDED AT A RATE OF 10% PER YEAR FOR EUROPEAN SUPPLIED EQUIPMENT AND 7% PER YEAR FOR ALL OTHER RESOURCES

SELECTED GROUND PROCESSING OPTIONS

Six sets of ground processing options were analyzed to determine programmatic implications. The selection of these sets, shown in Table 3-17, was based upon the following criteria:

1. Reflect the maximum spectrum of assembly and checkout prior to KSC-STS operations between generic ground processing concepts (Distributed, centralized, KSC).
2. Reflect the maximum spectrum of assembly and checkout prior to KSC-STS operations within generic concepts.
3. Reflect the maximum spectrum of Level IV integration GSE requirements.
4. Reflect the maximum spectrum of Level IV integration transportation requirements.

Table 3-17. Options Evaluated

OPTIONS	TYPE
A-1 A-3	DISTRIBUTED SITE
B-1 B-4	CENTRALIZED SITE
C-1 C-4	KSC OPTIONS

A generalized application of these criteria to the matrix of 12 processing options indicated that distributed site options A-1 and A-3, centralized site options B-1 and B-4, and KSC options C-1 and C-4 were preferred. The A-1, B-1, and C-1 options reflected only individual experiment/mounting element integration prior to initiation of KSC-STS operations. The A-3, B-4, C-4 options reflected the maximum level of integration of the payload within a generic option prior to KSC-STS operations. Transportation and GSE extremes are reflected between distributed site options (A-1 and A-3) and KSC options (C-1 and C-4).

A minor deviation from the generalized approach was required for the two pallet only representative payloads, Space Processing and Combined Astronomy. KSC-STS Level III assembly, which would correspond to an A-3 option, was not required for the Space Processing payload. Therefore, the A-2 option (no KSC-STS Level III assembly) will be used for the Space Processing payload in conjunction with the A-3 options for the other payloads.

Conversely, the Combined Astronomy payload does require Level III KSC-STS assembly regardless of the option used. Therefore, the B-3 and C-3 options for the Combined Astronomy payload will be used in conjunction with the B-4 and C-4 options, respectively, for the other payloads.

RESOURCE CATEGORIES

The programmatic analysis resulted in the definition of (1) Spacelab interfacing flight hardware, (2) Level IV Spacelab related GSE, (3) Level IV personnel requirements, and (4) transportation (to/from Level IV sites) requirements for each 6 options evaluated. The required inventory of flight hardware (i.e., racks, pallets, floor segments, RAU's, EPDB's, and cold plates) was derived from ground processing flows, payload configurations, and launch rates. The Spacelab related GSE requirements (processing and transportation) was determined from the Level IV installation, checkout, and integration activities. The personnel requirements include the direct "hands-on" integration manpower, TDY, Host Center support, and PI support for KSC operations. The transportation resources include those costs associated with the shipment of experiment, Spacelab flight hardware, and GSE to and from KSC to the various Level IV integration sites. The transportation costs will vary by each of the four payloads and by processing option within the same payload.

SPACELAB TRAFFIC MODEL EQUIVALENCIES

Initial effort in the programmatics task included the development of an equivalency between the four representative payloads defined in this study and the Spacelab traffic model. This equivalency is summarized in Figure 3-23.

Study Representative Payload	Traffic Model Payload		Configuration	Launch Schedule 80	81	82	83	84	85	86	87	88	89	90	91
Combined Astronomy	AS-01 SV-1 IR-1	Astrophysics	5 Pallets	0	0	0	1	2	4	4	5	4	4	4	4
	SV-2 SH-3	Solar Terrestrial	5 Pallets						2	2	2	2	2	2	2
	PA-1	Physics and Astronomy	5 Pallets			1	3	3	3	3	3	3	3	3	3
				0	0	1	4	5	9	9	10	9	9	9	9
Life Sciences	LS-09	Life Sciences	Long Module		2	2	2	2	2	2	2	2	2	2	2
ATL-A	AP-06	Solar Terrestrial	SH Mod + 3 Pallets				1	2	2	2	2	2	2	2	2
	ATL-1	Space Tech	SH Mod + 3 Pallets		1	1	2	1	2	1	2	1	2	1	2
	MU	Multi-User Applications	Long Mod + Pallet	1	1	3	3	3	3	2	2	2	2	2	2
	MU		SH Mod + 3 Pallets		1			2	2	3	3	3	3	3	3
	CSP01S COM-1	Non-NASA	Long Mod + Pallet						2	2	3	3	3	3	3
	FSP 01S	Foreign S/L	Long Mod + Pallet						1		1	1	1	1	1
	EON GPN	ESA	SH Mod + 3 Pallets				1	2	2	2	2	2	2	2	2
				1	3	4	7	10	14	12	15	14	15	15	16
Space Proc	MU	Multi-User	3 Pallet		1										
	ASN CSN	Foreign S/L	2 Pallet				1		1	1	2	1	2	1	1
	SS	Space Industrialization	Pallet Train		2	2	2	3	3	3	3	4	4	4	4
	SPN-5P	ESA	1 Pallet				1	1	1	1	1	1	1	1	1
	SPN-6P	W Germany	1 Pallet				3	3	3	2	2	2	2	2	2
					3	2	7	7	8	7	8	8	9	8	8

Figure 3-23. Spacelab Traffic Model Equivalencies

The Combined Astronomy payload equivalency is based upon multiple pallet trains and probable use of IPS and SIPS. Life Sciences is a continuing long module effort. ATL equivalency reflects multi-experiments that share racks and pallet segments. Similar technological disciplines are assumed to be grouped on each flight thus reflecting the applicability of limited distributed integration centers. It is assumed that space processing payloads are also included in the ATL equivalency group. The representative Space Processing payload used in this study is more akin to foreign, DoD, or commercial pallet only payloads.

MISSION MODELS

The Programmatic Analyses included the traffic model sensitivity analysis which was expanded to include all six ground processing option sets for the baseline traffic model, a two-thirds Spacelab traffic model, and a one-third Spacelab traffic model. All three traffic models are shown in Table 3-18. The baseline traffic model reaches a peak flight rate of 35 in the year 1989, with the 2/3 traffic model peaking in 1990, and the 1/3 traffic model peaking in 1985. The baseline traffic model is derived from the "560" mission model. The 2/3 and 1/3 baseline models are constructed from the baseline.

Table 3-18. Traffic Models for Programmatic Analyses

	Year / Type	1980	81	82	83	84	85	86	87	88	89	90	91	Totals
BASELINE	LS	-	2	2	2	2	2	2	2	2	2	2	2	22
	ATL	1	3	4	7	10	14	12	15	14	15	15	16	126
	CA	-	-	1	4	5	9	9	10	9	9	9	9	74
	SP	-	3	2	7	7	8	7	8	8	9	8	8	75
	Total	1	8	9	20	24	33	30	35	33	35	34	35	297
2/3	LS	-	1	1	1	1	1	1	1	1	1	1	1	11
	ATL	1	3	3	5	7	10	10	10	10	10	10	10	89
	CA	-	-	1	3	3	6	6	6	6	6	6	6	49
	SP	-	2	1	5	5	5	5	5	5	5	6	6	50
	Total	1	6	6	14	16	22	22	22	22	22	23	23	199
1/3	LS	-	1	-	1	-	1	-	1	-	1	-	1	6
	ATL	1	1	1	3	4	4	5	4	5	5	5	5	43
	CA	-	-	1	1	2	3	3	3	3	3	3	3	25
	SP	-	1	1	2	2	3	3	3	3	2	3	2	25
	Total	1	3	3	7	8	11	11	11	11	11	11	11	99

In order to reduce the amount of ground processing equipment required by conflicting launch dates, launch schedules were developed for each year of each traffic model. Figure 3-24 illustrates the launch schedule developed for the first four years of the Baseline Traffic Model.

The traffic models were established using the following ground rules:

EQUALLY SPACED LAUNCH CENTERS. The objective is to schedule the launch dates equally apart. A typical 5-day work week, 52 week year, was used as the standard. This resulted in a net of 260 total annual processing days per year. The number of 260 divided by the number of missions per year determines the schedule spacing.

ALTERNATION OF SPACELAB CONFIGURATIONS (where possible). If, in any given year, there are pallet and Spacelab module payloads, an attempt should be made to rearrange the schedule permitting an alternate sequence (i.e. pallet, module, pallet, module, etc.).

EVEN DISTRIBUTION WITHIN A GIVEN YEAR. This rule pertains to payloads having the lowest flight rate. For example, if only one such launch per year was scheduled, the subsequent flight would be scheduled 12 months after the first. Similarly, two flights per year would be scheduled six months apart.

1/3 BASELINE TRAFFIC MODEL

2/3 BASELINE TRAFFIC MODEL

YR	FLT NO	DAY	PAYLOAD LS	ATL	CA	SP
80	1	130		✓		
81	1	32		✓		
	2	65				✓
	3	97		✓		
	4	130	✓			
	5	162				✓
	6	195		✓		
	7	227				✓
	8	260	✓			
			2	3	–	3
82	1	29		✓		
	2	58				✓
	3	87	✓			
	4	116		✓		
	5	145			✓	
	6	174		✓		
	7	203	✓			
	8	232				✓
	9	260		✓		
			2	4	1	2
83	1	13				✓
	2	26		✓		
	3	39			✓	
	4	52		✓		
	5	65				✓
	6	78		✓		
	7	91				✓
	8	104	✓			
	9	117			✓	
	10	130		✓		
	11	143				✓
	12	156		✓		
	13	169				✓
	14	182		✓		
	15	195			✓	
	16	208	✓			
	17	221				✓
	18	234		✓		
	19	247				✓
	20	260			✓	
			2	7	4	7
84	1	10		✓		
	2	21				✓
	3	32		✓		
	4	43			✓	
	5	54		✓		

• 3 TRAFFIC MODELS
12 YRS/MODEL

36 ANNUAL LAUNCH SCHEDULES

• BASELINE TRAFFIC MODEL

Figure 3-24. Launch Schedule Development

The payload buildup and task sequences were prepared under the assumption that the integrating team was totally familiar with the payload. Subsequent provisions were made to accommodate for learning periods during the early portion of the flight schedule. A learning curve having a value of 80 percent with an operational steady-state activity achieved by the fifth mission passing through that Center was provided by the NASA (lower left corner of Figure 3-25). Based on this curve, the first payload through that center will require approximately 68 percent more time to process. The second, third and fourth payloads will require 34, 18 and 7 percent respectively. By the fifth payload passing through that center, it was assumed that it and subsequent payloads will be integrated per defined timelines in operational steady-state conditions.

Figure 3-25 indicates that a potential conflict can arise due to schedule extensions resulting from an overlapping need of core modules. The example is based on Option B-1 using the baseline traffic model. The clear bars indicate the payload integration times at a Centralized site. The shaded areas represent the Level III/II/I processing at KSC. ATL-3 and LS-1 will have a conflict indicating a need for the same piece of equipment (a second core module). The conflict can be alleviated by moving back the initiation of activities for ATL-3 sufficiently to avoid the conflict; or if schedules permit a delay to the initiation of LS-1 sufficiently to avoid the same conflict.

A learning curve analysis was made for the buildup of each traffic model with each option.

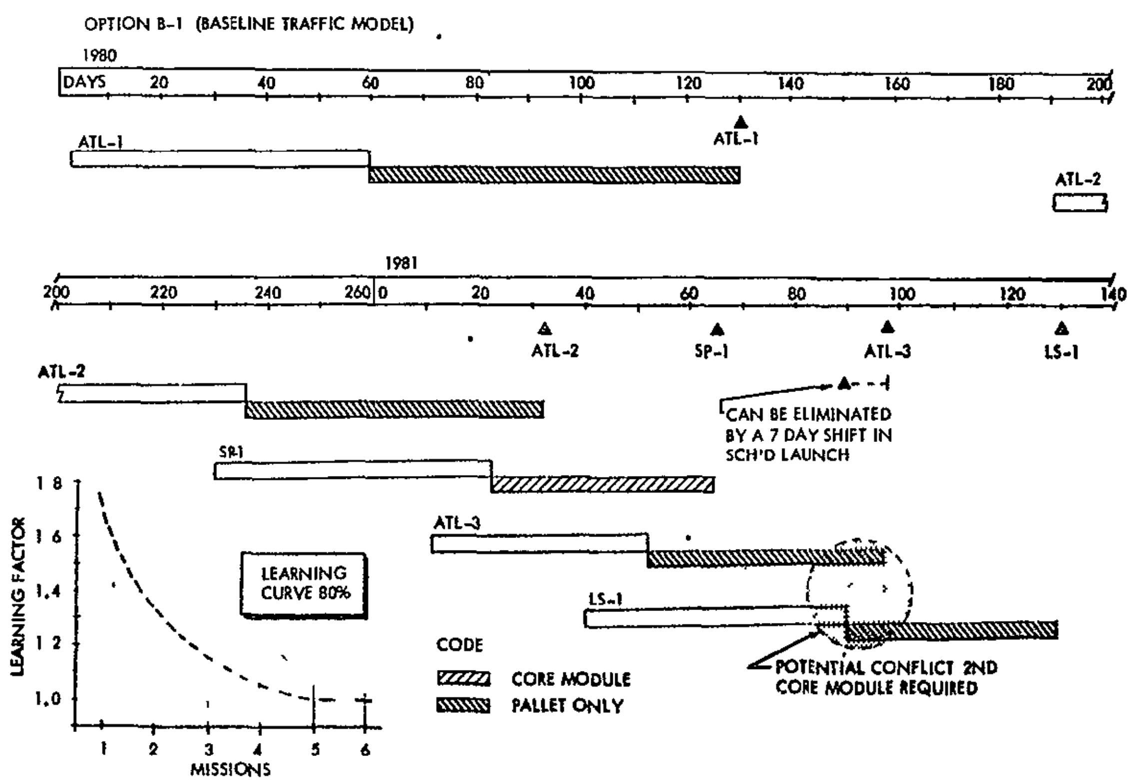


Figure 3-25. Learning Curve Analysis

ORIGINAL PAGE IS
OF POOR QUALITY

RESOURCE REQUIREMENTS

The resources required to support each option of three traffic models were defined for four major categories:

- Personnel
- Spacelab Unique Flight Hardware
- Level IV Integration GSE
- Transportation

Personnel Requirements

Test and Operations "Hands-on" personnel consists of technicians and engineers involved in the actual installation and checkout tasks associated with Level IV integration. Both engineers and technicians were considered as being multi-disciplined, i.e., both mechanical and electrical technicians and engineers were considered to be required for the different types of equipment and installations required. In deriving the manpower requirements, it was assumed that all distributed site "hands-on" personnel were PI employees, other than perhaps the support technicians. The centralized site options consisted of some of Host Center support and/or TDY. The KSC site options also consisted of some of Host Center support and/or TDY. The total manpower required, in terms of "headcount" was smoothed (weighted average) to provide a realistic manpower level.

The second category of personnel, referred to as Host Center Support, consists of those engineers and technicians provided at either the minicenter, lead center or KSC by the resident organization to provide support for nonresident PI personnel doing the hands-on effort. The third category of personnel are termed KSC Operations Support personnel consisting of PI personnel on TDY at KSC in support of Level III and subsequent operations on the payload. In conjunction with developing manpower levels and costs, a very significant part of total personnel costs is the Temporary Duty (TDY) allowance paid to traveling personnel, which varies widely with the processing option. A rate of $75 per day was used to determine the magnitude of this expense.

Table 3-19 is a summary of the personnel costs for each of the six options evaluated against the Baseline Traffic Model.

Table 3-19 . Personnel Costs for Baseline Traffic Model

OPTION	PAYLOAD									
	ATL		LIFE SCIENCES		COMB. AST		SPACE PROC.		TOTALS	
	M/P	TDY	M/P	TDY	M/P	TDY	M/P	TDY	M/P	TDY
A-1	24 44	3 91	4 25	0.48	12.36	1.48	8 93	1 58	49 98	7 45
B-1	25.20	4 91	3.59	0.75	12.88	1 92	9 30	2.10	50 96	9 69
C-1	25.96	7.31	3 72	1.17	13 39	4 59	9.75	3 23	52.82	16 29
A-3	28.22	5.17	4 66	0 68	15 32	2.37	9 23	1 58	57 43	9 79
B-4	25.45	6 17	3.48	0.77	12.58	2.74	9 60	2 10	51 11	11 78
C-4	26.33	9 58	3.70	1 23	13.02	4.44	10 05	3 30	53 10	18 55

- All costs in millions of 1977 $

The table has the similar processing options grouped together. Options A-1, B-1, and C-1 contain individual experiment checkout after installation and assembly, but they do not include an integrated payload checkout. Option A-3 is essentially a distributed option with the added element of having a combined payload checkout at the launch site prior to the commencing of the Level III/II integration in the O&C building. Options B-4 and C-4 contain a combined payload checkout at the Lead Center and KSC respectively. In these two options are comparable. In these two options, experiment equipment would be installed in/on the racks and floor segments. Individual experiment systems would be checked out followed by a combined payload checkout. The totally assembled and integrated payload would then be transported directly to the Level II stand in the O&C building. For the personnel costs evaluated by the study, the relative ranking, by cost, for each option is:

	$ M
A-1	57.43
B-1	60.65
B-4	62.89
A-3	67.22
C-1	69.11
C-4	71.65

Options A-1 and B-1 have the lowest total personnel costs because of their minimal TDY and Host Center Support requirements. In these two options, the Level IV integration effort is being performed at the "home" site for a larger majority of the PI's. These options are also lower in cost by virtue of not including an integrated combined payload checkout. From a personnel standpoing, the option that does provide for this higher confidence testing approach at the lowest personnel cost is Option B-4.

Table 3-20 contains a summary of the personnel costs for the 2/3 Baseline Traffic model.

Table 3-20. Personnel Costs for 2/3 Baseline Traffic Model

OPTION	PAYLOAD								TOTALS	
	ATL		LIFE SCIENCES		COMB. AST		SPACE PROC.			
	M/P	TDY	M/P	TDY	M/P	TDY	M/P	TDY	M/P	TDY
A-1	17 27	2.76	2.12	0 24	8 18	0 98	5 95	1 05	33 52	5 03
B-1	17 80	3 47	1.79	0.37	8 53	1 27	6 20	1 40	34 32	6 52
C-1	18.33	5.16	1 86	0.58	8 87	3.04	6.50	2.15	35 56	10 93
A-3	19 94	3 65	2.33	0.34	10.14	1 57	6 15	1 05	38.56	6 61
B-4	17 98	4.36	1 74	0.39	8 33	1 81	6 40	1 40	34 45	7 96
C-4	18 60	6 76	1 85	0.62	8 62	2 94	6.70	2.20	35 77	12 52

- All costs in millions of 1977 $

The same relative order holds for the personnel costs of the 2/3 Baseline Traffic model as for the Baseline. Option A-1 has the lowest total personnel costs ($38.55 $\bar{M}$), followed by B-1 ($40.84 $\bar{M}$), B-4 ($42.41 $\bar{M}$), A-3 ($45.17 $\bar{M}$), C-1 ($46.49 $\bar{M}$), and C-4 ($48.29 $\bar{M}$).

The personnel costs for the 1/3 Baseline Traffic model are summarized in Table 3-21.

Table 3-21. Personnel Costs for 1/3 Baseline Traffic Model

OPTION	PAYLOAD								TOTALS	
	ATL		LIFE SCIENCES		COMB. AST		SPACE PROC			
	M/P	TDY	M/P	TDY	M/P	TDY	M/P	TDY	M/P	TDY
A-1	8 34	1 33	1.16	0.13	4 18	0.50	2 98	0.53	16 65	2.49
B-1	8 60	1 68	0.98	0.20	4.35	0.65	3.10	0 70	17 03	3 23
C-1	8 86	2 49	1 01	0 32	4 53	1 55	3 25	1 08	17 65	5 44
A-3	9 63	1 76	1 27	0 19	5 18	0 80	3 08	0.53	19 15	3 27
B-4	8 69	2 11	0 95	0 21	4 25	0 93	3 20	0 70	17 08	3 94
C-4	8.99	3.27	1 01	0.34	4 40	1 50	3 35	1 10	17 75	6 20

- All costs in millions of 1977 $

If there is a separation between the engineering staff defining the integration requirements and analyzing the interfaces and the actual "hands-on" personnel then the coordination/liaison effort increases and the TDY costs increase accordingly. The TDY and Host Center Support costs for a given program would increase proportionately to the study TDY values from a low with the Distributed options, to a nominal value with the Centralized options to the highest values with the launch site options. All of these comparisons and trends are based on the groundrules of the majority (3/4) of the PI's being resident at a distributed site and one-half at the centralized site and none of the PI's being resident at the launch site.

Spacelab Flight Hardware

The quantities of Spacelab Flight Hardware required to support each of the four design reference missions were established by an analysis of the serial ground processing times for the element of Spacelab hardware being evaluated and by the proximity of launch dates for the payload being evaluated. The quantity of each of these items that are required to support a given program are determined by:

- involvement time in the ground processing flows of each option
- quantities required for a given payload configuration
- flight rate and launch schedule of the payload configuration for any given year of the traffic model.

The quantities of Spacelab unique flight hardware required to support the Baseline Traffic model are illustrated in Table 3-22.

Table 3-22. Baseline Traffic Model (Spacelab Flight Hardware Requirements)

EQUIPMENT ITEM	OPTION					
	A-1	B-1	C-1	A-3	B-4	C-4
CORE MODULE	3	3	3	3	3	3
IGLOO	3	3	3	3	3	3
IPS	1	1	1	1	1	1
SIPS	3	3	3	3	3	3
PALLET SEGMENTS	28	30	28	35	35	28
EXPERIMENT RACKS	26	30	26	30	30	26
RAU	54	54	54	54	54	54
EPDB	34	36	33	35	41	33
COLD PLATES	47	47	47	47	47	47
FLOOR SEGMENTS	7	7	7	7	7	7

The Core Module, Igloo, IPS and SIPS quantities have been included for reference only. The requirements for these major equipment items remain constant throughout each of the options because their involvement time is limited to the STS/Orbiter operations at KSC only and none of them is involved during the Level IV integration activities. The other six end items are involved during the Level IV ground processing activities and their requirements may vary by processing option. The Spacelab flight hardware quantities for the 2/3 and 1/3 Baseline Traffic model are summarized in Tables 3-23 and 3-24, respectively.

Table 3-23. 2/3 Baseline Traffic Model
(Spacelab Flight Hardware Requirements)

EQUIPMENT ITEM	OPTION					
	A-1	B-1	C-1	A-3	B-4	C-4
CORE MODULE	2	2	2	2	2	2
IGLOO	2	2	2	2	2	2
IPS	1	1	1	1	1	1
SIPS	2	2	2	2	2	2
PALLET SEGMENTS	20	20	18	20	20	20
EXPERIMENT RACKS	22	22	18	22	22	22
RAU S	36	36	36	40	36	36
EPDB	25	25	22	25	25	25
COLD PLATES	30	30	30	34	30	30
FLOOR SEGMENTS	5	5	5	6	5	5

Table 3-24. 1/3 Baseline Traffic Model
(Spacelab Flight Hardware Requirements)

EQUIPMENT ITEM	OPTION					
	A-1	B-1	C-1	A-3	B-4	C-4
CORE MODULE	1	1	1	1	1	1
IGLOO	1	1	1	1	1	1
IPS	1	1	1	1	1	1
SIPS	2	2	2	2	2	2
PALLET SEGMENTS	10	10	10	10	10	10
EXPERIMENT RACKS	14	14	14	14	14	14
RAU	22	22	22	22	22	22
EPDB	14	14	14	14	14	14
COLD PLATES	17	17	17	17	17	17
FLOOR SEGMENTS	4	4	4	4	4	4

The Spacelab flight hardware costs for all six options and each of the three traffic models are summarized in Table 3-25.

Table 3-25. Spacelab Flight Hardware Costs

	TRAFFIC MODEL		
OPTION	BASELINE	2/3 BASELINE	1/3 BASELINE
A-1	101.79	73 33	38 11
B-1	109 26	73.33	38.11
C-1	102.13	66.20	38.11
A-3	124 28	74 05	38.11
B-4	124.80	73 33	38.11
C-4	102.15	73 33	38.11

(All costs in millions of 1977 $)

These costs are influenced directly by the length of the ground processing times of each option evaluated. The longer the ground processing times the greater the quantities (and cost) of Spacelab flight hardware required to support the traffic model being evaluated.

Ground Support Equipment Requirements

The Ground Support Equipment (GSE) considered in this study was limited to that equipment required to support the installation and checkout of Spacelab equipment during the Level IV integration task. Equipment of a general purpose nature which would serve for installation/testing of experiment equipment as well as Spacelab equipment, such as multi-purpose sling sets, was included. Equipment especially designed for use with experiment equipment (furnished by the Principal Investigator) was assumed to be supplied by the P.I.

Because the GSE considered was designed for handling, transportation or testing (checkout) of Spacelab equipment, almost all of this equipment was taken from the Spacelab GSE Items Description Document (MSFC 40A99006) Rev. A. A few special items were conceived to support checkout of Spacelab-experiment interfaces and other tasks not effectively supported by the GSE in the referenced document. The GSE costs for all options and Traffic Models are summarized in Table 3-26.

In determining the GSE required to support the specific payloads studied, several considerations were made. First of all, it was assumed that only interface verification and functional verification would be performed, as opposed to specification testing.

Table 3-26. Summary of GSE Costs

OPTION	TRAFFIC MODEL BASELINE	2/3 BASELINE	1/3 BASELINE
A-1	10 76	7 95	7.32
B-1	5 68	3.79	3 40
C-1	3 78	2 19	1.59
A-3	12.13	8 89	7.73
B-4	5 38	4.75	3 18
C-4	3.47	2 03	1 44

(All costs in millions of 1977 $)

In the case of GSE, the launch site options have the unique advantage of one centralized location for Spacelab Level IV ground processing and thus the potential for the maximum amount of sharing between different payloads. The Centralized options (B-1 and B-4) have the capability to share GSE also but the fact that there are four centralized sites and that GSE is sent from/to a depot for each Level IV integration cycle, the resultant GSE costs for the centralized options are almost double those of any comparable Launch Site option.

Transportation Costs

The costs of shipment of Spacelab flight and GSE hardware to/from Level IV integration sites other than at KSC were predicated upon the total number of end items and the width of the shipment. No costs were included for shipment of experiment equipments. It was assumed that these costs would be independent of the processing option because the site of manufacture/assembly of the experiment equipment could be at a vendor, contractor, laboratory, university, etc., and thus, shipment to the integration site would be required in all options.

Two basic load types were identified: (1) the Standard Carrier and (2) the Outsized Carrier.

The Standard Carrier, sometimes referred to as a van, is a commercial-type vehicle such as a moving van or it may be a flatbed low-boy. It is of the type used daily on the public highway system without the need for special road permits for either excess weight or excess width (viz. wider than eight feet). The Outsized Carrier, in contrast to the Standard Carrier, is one which exceeds the normally accepted road widths of the public highway system. The need for such a vehicle is to accommodate the standard dual Spacelab pallet train.

After the various types of carriers were identified, trip durations were established. For standard carriers, a single (one way) trip was maximized at two days and for outsized carriers at five days for one-way trips while using public highways. When trips were necessary between facilities at KSC, the maximum allotted time for either carrier was one day. A similar analysis was performed to determine cost per trip. A summary of the transportation costs for all options and traffic models is presented in Table 3-27.

Table 3-27. Summary of Transportation Costs

	OPTION	TRAFFIC MODEL BASELINE	2/3 BASELINE	1/3 BASELINE
INDIVIDUAL EXPERIMENT CHECKOUT	A-1	10.05	6.61	3 31
	B-1	4 90	3.25	1.61
	C-1	0 97	0 65	0 35
COMBINED PAYLOAD CHECKOUT	A-3	10.28	6 77	3 40
	B-4	4.90	3 25	1.61
	C-4	0.97	0 65	0.35

(All costs in millions of 1977 $)

In all cases, the transportation costs for the launch site options (C-1 and C-4) are the lowest followed by the centralized options (B-1 and B-4) and the most expensive being the distributed options. For this resource, the costs are directly proportional to the number of flights in a given traffic model.

Programmatic Resource Summaries

The summation of the costs for Personnel, Level IV Integration GSE, Spacelab Flight Hardware, and Transportation costs for each of the six options of each traffic model are defined in this section. Graphs of the annual spending and cumulative spending requirements for all options evaluated against each traffic model are contained in Sections 3, 4, and 5 of Volume III.

Baseline Traffic Model

Table 3-28 contains the total Level IV ground processing resource summary for six options evaluated for the Baseline Traffic Model. The three lowest total cost options are C-1, C-4, and A-1 in that order.

Table 3-28. Total Level IV Ground Processing Resource Summary (Baseline Traffic Model)

PROGRAM RESOURCE	OPTION					
	A-1	B-1	C-1	A-3	B-4	C-4
FLIGHT HARDWARE	101.79	109 26	102.13	124.28	124 80	102 15
PERSONNEL	57 43	60.67	69 12	67 23	62 88	71 67
GSE	10.76	5.68	3.78	12.13	5 38	3.47
TRANSPORT'N	10.05	4 90	0 97	10.28	4 90	0.97
TOTALS	180 03	180.51	176.00	213 92	197 96	178.26

(All costs in millions of 1977 $)

-2/3 Baseline Traffic Model

Table 3-29 defines the total Level IV ground processing resources summary for the same six options of the 2/3 Baseline Traffic model. The lowest cost option is C-1 followed by B-1 and B-4.

Table 3-29. Total Level IV Ground Processing Resource Summaries (2/3 Baseline Traffic Model)

PROGRAM RESOURCE	OPTION					
	A-1	B-1	C-1	A-3	B-4	C-4
FLIGHT HARDWARE	73.33	73 33	66 20	74.05	73.33	73.33
PERSONNEL	38 57	40.87	46.52	45.19	42 45	48 31
GSE	7.95	3.79	2.19	8.98	4 75	2.03
TRANSPORT'N	6 61	3.25	0.65	6.77	3.25	0 65
TOTALS	126.46	121 24	115 56	134.99	123.78	124 32

(All costs in millions of 1977 $)

1/3 Baseline Traffic Model

Table 3-30 defines the total Level IV ground processing resource summary for the same six options of the 1/3 Baseline Traffic model. The three lowest cost options are C-1, B-1, and C-4.

Table 3-30. Summary of Option Costs (1977 $M)
(1/3 Baseline Traffic Model)

PROGRAM RESOURCE	OPTION					
	A-1	B-1	C-1	A-3	B-4	C-4
FLIGHT HARDWARE	38.11	38.11	38 11	38.11	38.11	38.11
PERSONNEL	19.16	20.27	23.10	22.42	21.02	23.97
GSE	7.32	3.40	1.59	7.73	3.18	1.44
TRANSPORT'N.	3.31	1.61	0.35	3 40	1.61	0 35
TOTALS	67.90	63.39	63.15	71.66	63 92	63.87

(All costs in millions of 1977 $)

3.5 CONCEPT EVALUATION

QUALITATIVE ASSESSMENT OF OPTIONS

In the establishment of a preferred ground processing concept, there are both quantitative and qualitative assessments that should be made in the selection of a preferred ground processing option.

In previous sections of this report, specific ground processing resource requirements were developed for each of the applicable options for each representative payload. Included in these resources were manpower, travel, GSE, flight hardware, and transportation/shipment costs. In addition to these factors, a relative comparison of the staffing, facility, GSE, operations, and management aspects of the alternate Level IV integration approaches was made (Table 3-31). Although aerospace firms and NASA centers are potential distributed site candidates, the evaluations for this approach are more indicative of industrial/commercial firms and university/science centers. Lead center evaluations assume either a major NASA aerospace center or a major aerospace contractor. Availability of appropriate facilities at KSC is assumed in the KSC evaluations.

These subjective evaluations indicate the following trends:

1. Distributed site options are the most advantageous for experimenters but probably the most complex for the Spacelab program.

2. Maximum use/minimum logistics of Spacelab equipment can be achieved with the KSC options, but experimenter logistics are maximum.

3. Lead center options provide a reasonable focal point/compromise between experiment and Spacelab program considerations.

4. Pre-KSC-STS operations will reduce the probability of incompatibilities between experiments and Spacelab and thus the potential for schedule impact on STS operations.

Table 3-31. Qualitative Assessment of Ground Processing Concepts

Category	Considerations	Distributed Site	Centralized	Launch Site
Personnel	Availability	Extension of development personnel already dedicated to experiment	Limited extension of experiment development personnel Potential for cadre of aerospace technician personnel - dependent upon flight rate	Minimum experiment oriented personnel Maximum potential for cadre of aerospace personnel
	Skill Mix	Excellent scientific/experiment but minimal aerospace/Spacelab skills Broad spectrum required among relatively small groups	Nominal scientific, excellent aerospace, potentially excellent Spacelab skills-dependent upon flight rate	Minimal scientific, excellent aerospace and Spacelab
	Relocation	Minimum - distributed sites are the experimenter's home base	Nominal - assumes some experiments are sponsored by lead center	Maximum - probably all experiment oriented personnel will be on TDY
	Duplication	Minimum scientific personnel duplication but maximum aerospace and Spacelab oriented personnel requirements because of multiple sites	Minor scientific Potentially minimum aerospace and Spacelab oriented personnel duplication - dependent upon flight rate	Assumed scientific personnel TDY Minimal aerospace and potentially negligible Spacelab personnel if S/L integration and/or staging personnel can also support level IV integration activities

Category	Considerations	Distributed Site	Centralized	Launch Site
Facilities	Availability	Assumed or a site will not be selected as a distributed site	Compatibility is an assumed prerequisite to be designated a lead center	Reassignment of industrial complex facility required
	Modifications	Access width/height and crane/cleanliness requirements may be constraints		Moderate modifications required
	Environment	Most familiar with experiment constraints which probably supercede Spacelab constraints Could be extension of experiment development environment		Established expertise in processing of scientific equipment
	Transportation Access	May limit viable candidate sites because over-the-road transportation and/or airport proximity		No constraints, air, barge, or road
	Safety	Potential hazards in handling size/weight of Spacelab elements		No constraints, standard operating procedures

Table 3-31. Qualitative Assessment of Ground Processing Concepts (Cont'd)

Category	Considerations	Distributed Site	Centralized	Launch Site
GSE	Availability	Maximum experiment related and special purpose Requires loan/logistics of Spacelab related GSE.	Nominal experiment and special purpose GSE Potential for adequate on-site Spacelab GSE-dependent upon flight rate and assignment of dedicated GSE	Limited experiment GSE Maximum spectrum of Spacelab GSE KSC assumed to be depot for Spacelab oriented GSE
	Inventory	Requires duplication of numerous items of level IV (Spacelab) GSE	One set of level IV GSE Could be dedicated - dependent upon flight rate	Minimum inventory because of proximity of GSE depot and potential for sharing numerous items
	Logistics	Minimum experiment but maximum Spacelab	Nominal experiment Could be minor/negligible Spacelab GSE logistics if flight rate supports dedication	Maximum for experiment related logistics but minimum/simplest for Spacelab GSE
	Maintenance	Excellent for experiment GSE but relatively poor for Spacelab GSE	Assumed relatively broad spectrum of scientific instrumentation capability plus partial payload sponsorship Spacelab GSE expertise dependent upon flight rate/dedication	Limited experiment GSE expertise but excellent Spacelab GSE maintenance capability - KSC is the assumed GSE depot

Category	Considerations	Distributed Site	Centralized	Launch Site
Operations	Level of Payload Assembly and Checkout	A-1 Minimum, individual experiment systems only A-2/3 Simulated payload mission checkout will be used	B-1 Minimum, individual experiment systems only B-2/3 Simulated payload B-4/5 Integrated payload configration	C-1 Minimum, individual experiment systems only C-2/3 Simulated payload C-4 Integrated payload configuration
	STS Operations and Schedule Risk	A-1 Maximum, only individual experiment systems verified in non-flight (payload configuration at multiple sites) A-2/3 Less than above option but still significant risk because of simulated payload configuration	B-1 Major, although comparable assembly and checkout as A-1, centralized activity would facilitate inter-experiment coordination B-2/3 Same as distributed site (Options A-2/3) B-4/5 Minor, transportation affects are primary concern	C-1 Same as lead center plus additional opportunity for closer coordination with Spacelab equipment staging activities C-2/3 Same as distributed site (Options A-2/3) C-4 Minimum, transportation should have negligible affect
	Transportation and Handling	Maximum for Spacelab equipment but minimum for experiment equipment	Nominal for both Spacelab and experiment equipment.	Nominal for Spacelab equipment (shorter duration) but maximum for experiment equipment

ORIGINAL PAGE IS
OF POOR QUALITY

Table 3-31. Qualitative Assessment of Ground Processing Concepts (Cont'd)

Category	Considerations	Distributed Site	Centralized	Launch Site
Operations (Cont'd)	Accommodation of Experiment Contingencies and Risks	Excellent because located at or close to experiment facilities	Nominal, assuming cadre of experiment oriented personnel	Minimum - Limited experiment oriented personnel
	Spacelab Equipment Maintenance	Minimum	Limited - dependent upon traffic rate and establishment of Spacelab	Excellent
	Assembly and Checkout Standards	Minimum standardization, however, readily adaptable or tailored to individual experiment requirements	Standardization with adequate flexibility for unique requirements.	Same as lead center
	Probability of Flight Hardware Damage/Misuse	Minimum for experiment equipment, maximum for Spacelab equipment	Nominal, assuming cadre of Spacelab oriented personnel is developed	Nominal
Management	Planning and Scheduling	Simplest, decentralized, and decoupled	Requires interrelationships and interdependencies to achieve desired efficiencies	Similar to lead center, simpler transportation but more complex GSE planning to achieve desired sharing/utilization
	Configuration Management	Probably simple and informal for experiments but complex/involved for Spacelab equipment	More rigorous for experiments, easier to coordinate for Spacelab	Some rigor for experiments and simplest for Spacelab

Category	Considerations	Distributed Site	Centralized	Launch Site
Management (Cont'd)	Documentation	Simple/informal for experiments Multiple and rigorous for Spacelab	More rigorous for experiments, simpler for Spacelab because of fewer items involved and development of expertise - dependent upon flight rate	Same level for experiments Transportation and GSE documentation differences between lead center and KSC concepts tend to offset each other
	Gov't Furn Equip (GFE) such as racks/pallets furnished for integration	Complex and interdependent	Readily controlled at the payload level	Readily controlled at the program level
	Logistics	Maximum effort required for Spacelab, minimum required for experiments	Nominal if lead center is partial payload sponsor	Maximum effort required for experiments and nominal for Spacelab equipment.
	Administration	Decentralized and decoupled for experiments but most complex for Spacelab	Nominal for both experiments and Spacelab	Same as lead center

3.6 DESIGN AND INTEGRATION GUIDE

This section is intended to provide guidelines to experiment designers to minimize the costs of Level IV integration and maximize the confidence in the Level IV assembly and verification procedures. The guidelines were developed as a result of the experience gained in this study, in conceptually integrating a broad range of experimental equipment into standard Spacelab carrier elements. These guidelines are presented in an arbitrary order, not in order of importance or precedence.

1. In rack installations, all end items from a single experiment should be installed in the same rack where possible. If the size and number of end items precludes this, all items should be installed in adjacent racks on the same side of the same module segment. If neither of these schemes is feasible, the items should be installed in racks across from each other.

   Installation of experiments in this manner reduces cable and plumbing lengths to a minimum, with attendant savings in installation time and weight. Also, the shorter wire runs result in less exposure to possible EMI effects from other experiments. In some cases, fewer interconnections may be required, which reduces installation time, hookup time, verification requirements, checkout equipment complexity and general ground processing time. If an experiment is unnecessarily spread between two racks, and one of the racks is integrated at a different site than the other, unnecessary travel time and GSE expense are required, as well as additional interface verification when the two racks are joined.

2. In pallet installations, the same general guidelines apply. All equipment for a given experiment should be installed on the same pallet whenever possible. Where length of a subassembly requires that it be installed on two or more trained pallets, it should be so designed that the end items may be installed principally along one side of the pallets, freeing the other side for other installations.

   As with rack installations, this practice will minimize cable and plumbing lengths, with savings in weight and installation time. Again, EMI effects from Orbiter, Spacelab or experiment sources is also minimized. The above comments on the savings in avoiding unnecessary additional interconnections also apply, in that such practice reduces installation time, hookup time, verification requirements, checkout equipment complexity and general ground processing time. The practice of keeping a multi-pallet installation to one side of the pallets, in addition to the above savings, also allows for fuller utilization of available pallet installation space.

3. Experiment equipment should, when feasible, provide for multiplexing of data within the experiment such that a minimum of output channels of data must be accommodated by Spacelab subsystems.

   This practice reduces the amount of signal/control wiring between the experiment end items and Spacelab subsystem RAU's, thereby reducing weight, installation time, EMI problems, connection interfaces and the other items mentioned above in connection with excess wiring. In addition, the smaller number of data channels reduces the burden on Spacelab subsystems, such that the need for extra RAU's, with their cost and installation time, is avoided.

4. Use data bus channels in preference to hardlines for all but the safety critical control functions.

   By following this guideline, the number of direct hardwires to Orbiter control and display panels is reduced to a manageable number. The data bus in the Spacelab can handle many times more functions in the same amount of wiring as one-by-one hardlines. Of course, on some safety critical functions where crew or Orbiter safety could be jeopardized in the event of a Spacelab data bus failure, a hardline is justified and required.

5. Experiment equipment should be designed such that all end items can be easily mounted in close proximity to each other and to data/control and power interfaces.

   This again reduces wire run lengths, with attendant weight and installation cost savings, as well as EMI effects, excess connectors and the other effects of excessively long wire runs.

6. Wherever possible, experiment end items should be pre-assembled by the Principal Investogator into easily installed assemblies. An example of this approach is the pre-assembly, in the ATL payload, of the three antennas of the Microwave Radiometer experiment onto one support structure, together with the RF enclosures, main and auxiliary control units for each of the three antennas.

   Preassembly of a number of end items into one unit in this fashion, though it may add to the effort and cost at the Principal Investigator's facility, has a number of advantages. The savings in installation time on the Spacelab carrier (pallet or rack) for both end items and associated cabling/tubing is appreciable, and would certainly offset the increased effort at the PI's site. In most cases, the PI must assemble the end items on some kind of support structure for final testing anyway, and this assembly can then be maintained into Level IV integration. Second, this kind of preassembly makes transportation and handling of the equipment much simpler, reducing transportation time and

cost as well as GSE utilization. Also, the support and protection afforded by such a structure enhances the reliability of the overall experiment by reducing potential damage in handling and installation.

7. Test Procedures, mechanization and software for performance of experiment (and payload) interface verification should be as simple as possible, and experiment hardware should be designed to this goal. Since it is assumed that the experimenter will perform all specification performance testing on his equipment, only verification of interface connections, fluid and electrical, should be required at Level IV.

   Simplification of these checkout requirements at the design Level will save large amounts of testing, data reduction and data analysis time and manpower resources. This in turn results in reducing both total integration cost and serial processing time, and increasing the potential annual flight rate.

8. Experiment hardware should, where feasible, include a self-test capability to permit verification of basic operating functions.

   Incorporation of this feature can greatly simplify troubleshooting when interface verification testing results in ambiguities. Isolation of apparent malfunctions as either interface problems or experiment equipment problems is thereby made far simpler. This self-test feature, of course, would not be used to actually perform interface verification tests.

9. Support equipment items within an experiment should be combined, by either functional design or packaging, such that the number of such end items is minimized. For example, power conditioning, power supplies and control units for several furnaces in an experiment can be combined into one unit.

   Combination of support items in this manner results in savings in Level IV installation time and manpower, as well as fewer interfaces between experiment units and with Spacelab subsystems. Also, the fewer number of interfaces simplifies Level IV checkout activities and enhances confidence.

10. In the experiment design phase, an optimization should be reached between design cost/weight/complexity and reliability. Added capacity and complexity to enhance redundancy and reliability is to be avoided, beyond a certain point of optimization.

    This type of optimization, wherein complexity and cost are traded off against ultimate reliability, can result in considerable savings in not only equipment cost (not a concern in this study) but also weight, power requirements, installation complexity and checkout requirements.

11. In the design of internal and external wiring for experiment equipment, every attempt should be made to keep signal and control wiring separated from power wiring, either AC or DC power. This separation will be continued in all external wiring on Spacelab harnesses, and interface connections on experiment equipment should be designed to facilitate this separation.

    This design guideline implements general aerospace practice in preventing generation of spurious Electromagnetic Interference (EMI) on signal or control lines from fields generated by power lines nearby. Although twisted, shielded pairs and shielded, grounded coaxial cable is used, such EMI is still potentially possible when power spikes are of sufficient magnitude or shields are inadequate or inadequately grounded. Such interference can then result in incompatibility between experiments in a payload or even between end items of the same experiment.

3.7 SUMMARY

Conclusions

There were four major conclusions that can be drawn from the data evaluated as a part of this study. The initial point is that from an analysis of the programmatic ground processing resource requirements of the four representative payloads and the six ground-processing options analyzed there were no conclusive cost discriminators between the ground processing options. The two centralized options - Lead Center and KSC - did tend to be somewhat less expensive but the deltas were less than 10 percent overall.

The Ground Processing cost differences between the six options evaluated for the three traffic models are not sufficiently large enough to be considered as discriminators that of themselves could be used to establish a preferred agency ground processing approach. In the baseline traffic model, the cost difference between the four lowest cost options is 4.51 Million dollars (1977 $) from a cost spread of $176.0M to $180.51M. This represents a percentage difference of 2.6%. In the 2/3 Baseline traffic model the difference was $8.76M (7.5%) between the first and the fourth costly option. In the 1/3 Baseline, the difference is $0.77M and represents a 1.2% difference.

The second major conclusion comes from an analysis of the cost of an integrated payload assembly and checkout. If the cost differences between those options that included an integrated off-line payload assembly and checkout (A-3, B-4, C-4) are compared to those that only included an individual experiment checkout after installation, a minor savings results. For the baseline traffic model and the KSC options (C-4 and C-1), only a 1.3% savings occurs. The Centralized site options (B-4 and B-1) differences are 9.6%. For the 2/3 Baseline traffic model, the differences between combined payload checkout and individual experiment checkout are KSC options 7.6% and Centralized 2.1%. The 1/3 Baseline traffic model differences are even smaller.

Integrated payload assembly and checkout prior to the initiation of the Spacelab Level III/II operations is preferred. Completing this test prior to the O&C Spacelab/STS operations will provide an increased confidence that the experiments and Spacelab equipment integrated together will function properly as a payload. There also exists the potential that this integrated "off-line" payload assembly and checkout may reduce the future planned Level III/II activities by reducing the scope or completely eliminating some Spacelab Level III/II activities. The average cost of the integrated pre-Level III/II ground checkout is approximately $25,000 per mission. In light of the total ground processing, mission, experiment costs, this additional investment seems appropriate. This added cost may be completely offset by the possible reduction of Level III/II ground processing.

The Distributed site options require substantially greater GSE inventories and significantly greater transportation shipments and costs. The Distributed site options require twice as much cost for GSE as do the Centralized options. The Distributed site options also require almost four times as much GSE as the corresponding KSC options. The Distributed site options require so much more GSE because of the large number of such sites (15) compared to the four Centralized sites and the single KSC launch payload processing area. The GSE costs associated with the larger number of Distributed sites is offset somewhat by the fact that at each distributed site there is a unique complement of GSE that are shipped to complete the specific ground processing of Spacelab flight hardware and experiments at that location. At the Centralized sites and at the Launch Site, there is one complete set of GSE and the processing on the experiments and the Spacelab equipment are scheduled to avoid conflicts and the requirement for additional GSE. Additional GSE are required in the Centralized and Launch Site options only when the flight rate requires it.

The same cost differences are true for the transportation deltas. The Distributed options require twice as much cost as their Centralized counterparts and 8 to 10 times as much cost as the Launch Site options. These higher transportation costs for the Distributed options are directly related to both their large number of locations (15 as opposed to 4 Centralized sites and 1 Launch Site) and the concept of shipping the GSE in all options from a launch site depot. Taking a payload like the Advanced Technology Laboratory (ATL) and allocating the Spacelab hardware to the three logical (by experiment groupings) Distributed sites increased the transportation costs in these examples by a factor of almost 3. Similar increases were experienced in the Life Science, Space Processing and Combined Astronomy payloads.

The fourth major conclusion that can be drawn from the study results is that the differences in recurring costs between options are minimal. The "recurring" costs used here refer to the Level IV hands-on manpower, TDY and transportation costs. These costs are incurred after the initial complement of Spacelab flight hardware and GSE have been acquired. Figure 3-26 illustrates the cumulative spending requirements for each of the six options evaluated in the programmatics task) against the 2/3 Baseline traffic model.

The rate of expenditure during the recurring portion of these programs (last 7 of 12 years) represents the portion of these options when the majority of the capital investments have been made and only the transportation and personnel costs are being spent to complete the Level IV integration on the Spacelab flights. The curves are essentially linear (exception being the C-4 option) and the order at the end of the 12th year of the program is almost identical to the relative positions (with respect to cumulative spending) at the fifth year of the program. The involvement times for the ground processing associated with option C-4 are just long enough that at the annual flight rate (23 Spacelabs) of the last two years of the program approximately eight million dollars of additional flight hardware are required to support the increased flight rate. Option C-1 goes from a cum of $84M in 1985 to a program total of $115.6M in 1991. Thus, in the last six years of the program, the lowest cost option spends $31.6M for the Level IV ground processing costs of 134 Spacelab flights or approximately $240,000 per flight. The $84M spent in the first six years of the program accumulated the required inventory of Spacelab flight hardware and Level IV integration GSE while supporting the missions of 65 additional flights. The average Level IV ground processing costs for all 199 flights of the 2/3 Baseline traffic model, utilizing option C-1, are approximately $600,000 per flight.

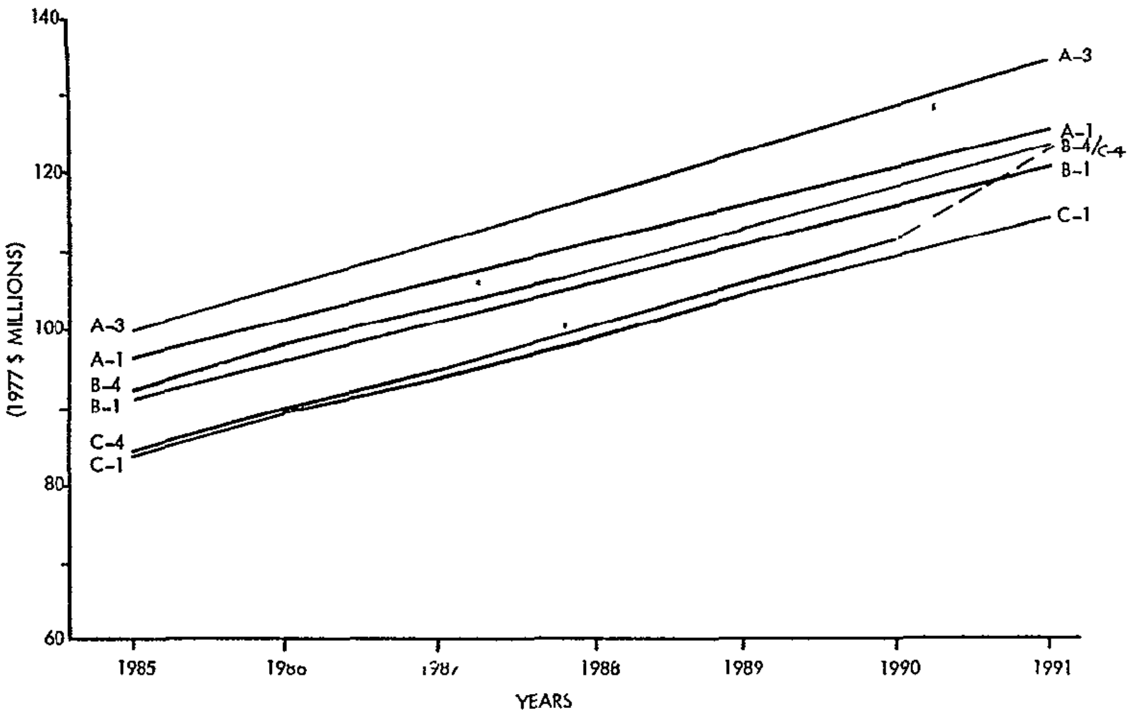


Figure 3-26. Recurring Costs 2/3 Baseline Traffic Model

Study Recommendations

From the data analyzed during the study and the results of the system level trade studies, there are specific points or study recommendations that were developed.

- Flight floors, RAU's, cables, and fluid lines should be used during Level IV integration instead of substitutes.

  The system trades (Section 3.3) proved that it was cost effective to use these end items rather than simulators or substitues. In each of these four cases, substitution was not recommended because of the additional costs that would be incurred were not offset by the reduction in use of the flight equipment.

- IPS and SIPS involvement should be deferred until Level III/II Integration

  For the more expensive IPS and SIPS substitution is indicated and recommended based on the cost savings (up to $52,000 for the SIPS and up to $340,000 for the IPS). Therefore, it is recommended that the use of these two flight hardware end items be deferred until the Level III/II integration is accomplished at the Launch Site.

C-2

- Shared Spacelab Equipment (Progressive Integration) is not cost effective - applicable only to unique payload situations.

  The progressive integration trades indicated that for all cases considered that the per mission ground processing costs would be anywhere from 10 to 20% higher utilizing a shared Spacelab equipment integration approach. The only applicability for this approach would appear to be special cases where unique laboratory equipment existed and it would not be practical to move the lab equipment.

- Dedication of: Racks should be considered at flight rates ≥ 2/year
  Pallets should be considered at flight rates ≥ 4/year

  The effects of dedicating selected pieces of Spacelab equipment to specific experiments were explored and analyzed. The dedication of Spacelab racks appears to be cost effective at 2 or more flights per year. With a pallet segment, the requirement rises to 4 or more flights per year to be cost effective.

- Flight hardware inventory differences are small and mission model dependent-synthesize the traffic model based on the anticipated Spacelab flight hardware complement.

  There are differences in the Spacelab flight hardware requirements of the three traffic models. The Baseline traffic model requires 3 core modules and Igloos, which the 2/3 and 1/3 traffic models require 2 and 1 respectively. Pallet segments quantities vary from a maximum of 35 (Baseline Option A-3) to 10 (1/3 Baseline all options). There are similar differences for other equipment items. The total listing of Spacelab equipment items requirements are contained in Tables 3-22, -23, and -24.

  However, the flight hardware inventory differences between options of a given traffic model are small (Baseline traffic model the differences are: maximum of 7 pallets, 4 experiment racks, and 6 Experiment Power Distribution Busses) and are mission model dependent. For example, in the 1/3 Baseline traffic model, there are no flight hardware differences between any of the six options. The future traffic models may be defined from an analysis of the planned complement of Spacelab flight hardware rather than the reverse. A traffic model synthesized from a specific planned flight hardware complement might provide a more accurate comparison of option deltas and cost differences.

4.0 PROPOSED ADDITIONAL EFFORT

4.0 PROPOSED ADDITIONAL EFFORT

The various elements of the ground processing activities for the processing options derived in the study were developed and evaluated to a uniform depth. However, in the process of the completion of the study it became apparent that certain items/topics could have a significant impact on the final selection of a preferred agency approach. A more detailed analysis of these topics could enhance an understanding of the differences between the options analyzed. A brief synopsis of the factors that warrant additional analysis effort is presented in the following paragraphs.

ANALYTICAL ENGINEERING AND INTEGRATION

In considering the personnel requirements for Level IV Integration, the personnel involved have been limited to "hands-on" personnel - the technicians, supervisory engineers, inspection, support equipment operators and others working directly on the payload hardware. An additional body of support personnel required for such operations are engineers involved with development of the detailed integration procedures, drawings, support equipment design, specification preparation and administration. Analysis of these additional requirements would make the total cost factors and differences considerably more complete.

IMPACT OF LEVEL IV INTEGRATION APPROACH ON LEVEL III/II ACTIVITIES

Detailed planning data on specific Spacelab payload operations to the level of detail required to establish the experiment related portion of the Level III/II flows were not available during the course of the study. Therefore, in the analysis of the various processing options for Level IV integration, no consideration could be taken of the influence each option might have on subsequent integration efforts in Level III and II at KSC. In fact, the choice of a Level IV option is sure to affect Level III/II efforts, with time and cost impacts. These factors should be studied further.

UTILIZATION FACTORS

The various processing options considered have differing degrees of utilization of the flight hardware and the GSE. This has been incorporated to the extend of prorating the flight and GSE hardware costs. The actual percent utilization of hardware for each option in each traffic model has not been developed or reported, however, and would be a useful parameter to consider in selecting an option.

EXISTING/PLANNED NASA/CONTRACTOR LEVEL IV INTEGRATION CAPABILITIES

This study has not considered what facilities exist or are planned at KSC or other potential sites. Factoring this information into the study would increase the utility of the results.